RESPONSE OF A PANGOLA DIGITGRASS-GLYCINE PASTURE TO GRAZING MANAGEMENT

By

EDUARDO GUILLERMO CANUDAS-LARA

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1988

IN MEMORY OF

GERALD O. MOTT

"an extraordinary scientist that devoted his life
to pasture-animal research"

The author is grateful to Dr. Mott for sharing his knowledge and experiences in pasture-animal relationships and for his assistance in the planning of the dissertation research.

ACKNOWLEDGMENTS

The author would like to express his sincere appreciation to the chairman of his supervisory committee, Dr. K. H. Quesenberry for his support, advice, and guidance throughout the academic program.

He also wishes to express his gratitude to Dr. W.D. Pitman, cochairman of the supervisory committee, for his wisdom and encouraging suggestions.

Grateful appreciation is extended to Dr. L.E. Sollenberger for his constructive criticism and remarks throughout the research. The special friendship that has joined both families will always be remembered.

The author is also thankful to Dr. J.E. Moore and Dr. C.J. Wilcox for their outstanding contribution to this research.

The author is indebted to the University of Florida, and the Colegio de Postgraduados and the National Institute of Forestry, Agronomy and Animal Science of Mexico for their financial support during the academic program and field work. Particular appreciation is extended to Dr. H. Roman, Dr. L. Jimenez, Dr. A.

Saldivar, Dr. M. Cuca, Dr. D. Riestra, M.S. H. Castillo, M.S. H. Barradas, and M.S. C. Olguin for their support.

Special thanks are given to Eusebio Ortega and Rene Rivera for their invaluable support and their unconditional help that made possible the successful completion of the field work, and also to Miguel A. Martinez for his appreciable contribution.

The author is also most grateful to Mrs. L. Mott for her care and kindness to the author and his family, and to Caty and Alfonso Ortega for their help and friendship that have united both families.

The author wants to extend his gratitude to his parents, Martha and Eduardo, for over 30 years of unlimited help and support.

Finally, the author wants to express his appreciation to his wife, Judy, for her unconditional love and support throughout all these years that have made it all possible, and to his children Eduardo and Lorena for their patience and understanding, particularly in those times that were supposed to have been used for recreation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

Abstract of Dissertation Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

RESPONSE OF A PANGOLA DIGITGRASS-GLYCINE PASTURE TO GRAZING MANAGEMENT

By

EDUARDO GUILLERMO CANUDAS-LARA

August 1988

Chairman: Kenneth H. Quesenberry
Cochairman: William D. Pitman
Major Department: Agronomy

Grass-legume pastures are a potentially important alternative for increasing livestock production in tropical areas. Productivity and quality of tropical pastures can be improved with better grazing management and by incorporating legumes in grass swards. Advantages of legumes have been clearly manifested and are well documented in the literature.

An existing 1-ha area of 'Pangola' digitgrass (<u>Digitaria decumbens</u> Stent) and glycine (<u>Neonotonia wightii</u> [R. Grah. ex Wightii and Arn.] Lackey) cv. Clarence located in Veracruz, Mexico (Lat. 19°N, Long. 96°W, Alt. 10-16 m) was used in the study. Annual precipitation is approximately 1750 mm in a well-defined rainy season from June to November, and mean annual temperature is about 25°C. The treatments were arranged in a complete factorial in a randomized complete

block design with two replications. The two grazing management variables were grazing cycle (GC; Continuous, 21, 42, or 63 d) and residual dry matter (RDM; 2, 4, or 6 Mg ha^{-1}). The data were analyzed by response surface methodology using least squares regression.

During the 147-d grazing season, as RDM and GC decreased the following responses were observed. (1) Mean live pregraze dry matter (DM) herbage mass decreased linearly (7.3 to 2.1 Mg ha^{-1}; $P<0.01$). (2) Glycine percentage decreased quadratically at a decreasing rate (15 to 0%; $P=0.03$) for RDM, and linearly ($P=0.04$) for GC, but at low RDM glycine percentage was low, regardless of GC. (3) Total DM accumulation increased linearly (1.7 to 9.5 Mg ha^{-1}; $P<0.01$). (4) Total DM consumption also increased (2.5 to 10.2 Mg ha^{-1}), but only was affected by linear effect of RDM ($P<0.01$). Forty-seven percent of the variation in live pregraze herbage mass, and over 74% in total DM accumulation and consumption were explained by RDM. (5) Mean growth rate increased linearly (1.4 to 8.4 g m^{-2} d^{-1}; $P<0.01$).

Mean crude protein (CP) of pregraze whole-plant samples of Pangola and glycine was 81 and 148 g kg^{-1} DM, respectively; and mean in vitro digestible organic matter (IVDOM) was 488 and 530 g kg^{-1} OM, respectively. Mean CP for Pangola and glycine of DM consumed was 92 and 168 g kg^{-1} DM, respectively; and mean IVDOM was 558 and 572 g kg^{-1} OM, respectively.

INTRODUCTION

Researchers' efforts have concentrated on increasing yield and quality of tropical grasslands through the introduction of superior species or varieties of grasses and legumes and through better management practices. The major source of nutrients for beef or dairy enterprises in the tropics is from forages, but tropical species have generally not supported the levels of animal production observed with temperate species.

It is agreed, however, that beef production from improved pastures offers the best prospect for meeting the increasing demand for animal protein. The great value of cattle (Bos spp.) lies in their ability to convert plant material, that is indigestible to humans and grown on land which cannot otherwise be used for food production, into human food. Increases in pork and poultry production and the feeding of cattle on feedlots results in greater dependence on feed grains, for which arable land is required. In contrast, improved pastures can be grown on non-arable land which at present is not being fully exploited (Mannetje, 1978).

The concept of tropical grass-legume pastures is now widely accepted, but development of such pastures has been slow. Legumes are very important in animal grazing systems due to their nutritive value and N fixation ability; consequently, an increase in the interest of researchers in evaluating tropical legume-grass associations has been observed.

'Pangola' digitgrass (Digitaria decumbens Stent) has become a very important forage species in tropical and subtropical regions. Pangola is an aggressive grass, but in several experiments it has been successfully associated with tropical legumes (Monzote and Garcia, 1983; Monzote and Hernandez, 1977; Lopez and Paretas, 1982; Garza et al., 1972; and Kretschmer, 1970). Glycine (Neonotonia wightii [R. Grah. ex Wightii and Arn.] Lackey) is a valuable pasture legume, and it is capable of increasing milk and beef production of cattle grazing tropical pastures (Anon., 1976; Cowan et al., 1975; Garza et al., 1978; and Paterson and Horrell, 1981). Advantages of associations of legumes and grasses have been manifested and are well documented.

The area selected to conduct this research was chosen from a 12-ha grass-legume production module (Garza et al., 1978). The module consisted of 3 ha of Pangola digitgrass alone, and 3 ha of each of the following associations, Pangola-glycine, Pangola-centro

(Centrosema pubescens Benth.), and Pangola-leucaena (Leucaena leucocephala [Lam.] de Wit). The author chose to study the association of Pangola-glycine instead of centro or leucaena. The reasons are because glycine had performed very well at this location and was more aggressive than centro, and because leucaena has a shrubby growth habit, and it is not fully accepted by the local cattlemen. Throughout the years, glycine percentage has diminished substantially, perhaps due to inadequate grazing management. Nevertheless, establishment of tropical legumes has been of increasing interest in the region. Therefore, a grazing study was designed with the following objectives: 1) to study the growth and defoliation pattern of the association under various combinations of residual dry matter after grazing (as a measurement of grazing intensity) and length of grazing cycle; 2) to determine the effect of several grazing management strategies on productivity, persistence, and botanical composition of the association; and 3) to estimate the nutritive value of the herbage mass and herbage consumed.

LITERATURE REVIEW

Tropical Forages

Pangola Digitgrass

Digitaria is a large genus with over 300 species of annual or perennial grasses, mainly tropical and subtropical but also of warm temperate areas, and it is almost exclusively of African origin. The most valuable cultivated species of this genus is *D. decumbens*. Several other species are currently under evaluation, such as *D. pentzii*, *D. milanjiana*, *D. setivalva*, *D. smutsii*, and *D. valida*. These species grow in relatively dry parts of Africa with annual rainfall ranging from 500 to 1000 mm with one or two well-pronounced dry seasons (Bogdan, 1977).

Pangola digitgrass has become one of the most important forage species in the Caribbean, Central America, and in the subtropical regions of North and South America (Nestel and Creek, 1962). It is best adapted to regions with over 1000 mm of annual rainfall. It is described by Bogdan (1977) as a vigorous, strongly

stoloniferous perennial grass, with long creeping stolons that root from the nodes. The leaves are numerous, glabrous, linear-lanceolate to linear, 10 to 25 cm long, and 0.2 to 0.7 cm wide. The inflorescence is a terminal digitate panicle of 5 to 10 spikes (raceme), usually arranged in one whorl. The spikes are up to 13 cm long, densely surrounded with paired spikelets, with one sessile and the other on a short pedicel. Spikelets are generally about 3 mm long, with two florets. The lower glume is very small, and the upper one is three quarters of the length of the spikelet.

Pangola digitgrass is propagated by stem cuttings because it produces very little viable seed. The simplest and most common way to establish it is to cut the herbage when it is stemmy, spread 0.5 to 2 Mg ha^{-1} of fresh material on a prepared seedbed, and disc it into the soil (Bogdan, 1977). If the ground is too wet for tractor disking, cattle trampling can press the stems into the soil (Nestel and Creek, 1962).

Average dry matter (DM) yields with moderately to well fertilized Pangola range from 11 to 22 Mg ha^{-1} (Nestel and Creek, 1962). Crude protein (CP) and in vitro digestible organic matter (IVDOM) concentration decline rapidly with advancing maturity. Ventura et al. (1975) reported decreases in CP for first and second regrowth of Pangola hay from 180 to 50 g kg^{-1} DM and

IVDOM from 680 to 500 g kg^{-1} OM when maturity increased from 2 to 12 weeks. Also, Virguez (1965) reported a decrease in CP of Pangola digitgrass from 150 to 75 g kg^{-1} DM with an increase in maturity from 10 to 45 d. Other reports state that Pangola CP ranged from 60 g kg^{-1} DM when unfertilized or fertilized with a very low level of N, to 120 g kg^{-1} DM with a N application of 1.8 Mg ha^{-1} (Nestel and Creek, 1962).

Glycine or Perennial Soybean

Glycine or perennial soybean is the common name of the tropical legume *Neonotonia wightii* (R. Grah. ex Wightii and Arn.) Lackey. The botanical classification has been changed several times; therefore, it is found in the literature as *Glycine wightii* (R. Grah. ex Wight and Arn.) Verdcourt, *G. javanica* L., *G. micrantha* Hoscht, and *Hedysarum spicatum* Boj (Skerman, 1977). The common name "glycine" comes from the old botanical classification.

Most tropical legumes originate in tropical America, but this specie originated in Africa, and it is found from tropical Asia through east and central Africa and down to South Africa. It is a summer-growing perennial in subtropical regions, but can grow year-round under frost-free conditions (Skerman, 1977).

Glycine is a herbaceous perennial legume with a strong taproot, and trailing, climbing, and twining stems. The slender stems are well branched, and under grazing can arise from a crown below the soil surface. The runners frequently root at the nodes and are moderately hairy. Leaves are pinnately trifoliate with ovate leaflets that are 5 to 10 cm long and 3 to 6 cm wide. There are short hairs on both surfaces, and leaves have small triangular stipules. The flowering racemes are elongated and range from 4 to 30 cm in length, with white or violet flowers that are 0.5 to 0.8 cm long. Pods are hairy, straight, or slightly curved. They are about 1 to 4 cm long and 0.3 cm wide, and contain from 3 to 8 seeds. Seeds vary in size, shape, and color depending on variety (Skerman, 1977).

Glycine is best adapted to areas where summer rainfall is from 750 to 1500 mm, and it does not perform as well in areas of higher rainfall. It is reasonably drought tolerant probably due to its deep persistent taproot that forms when it is well established. It grows slowly during dry spells but recovers quickly when favorable conditions resume (Skerman, 1977).

Glycine is more demanding in its soil requirements than some tropical legumes. It performs best in deep, well-drained soil, and it is not tolerant of flooding (Humphreys, 1980a). It does not grow in very acidic soil

and grows best at pH above 6.5 (Skerman, 1977). However, it shows reasonable tolerance to salinity compared to other tropical legumes, but salinity may inhibit growth, nodulation, and N fixation (Gates et al., 1966a; and Gates et al., 1966b).

It is not Rhizobium specific, and it nodulates well with cowpea type Rhizobium (Kennedy, 1962). Other authors mention that glycine is capable of establishing an effective symbiosis with the natural Rhizobium of many agricultural soils (Lopez et al., 1981; and Whiteman, 1972). Johansen and Kerridge (1979) concluded that glycine can fix 100 to 140 kg N ha^{-1} yr^{-1}. Lopez et al. (1981) mentioned that it is possible for glycine to fix 240 kg N ha^{-1} yr^{-1}, and about 130 kg more if the soil is fertilized with Ca, P, K, B, and Mo. This agrees with Lopez and Paretas (1982), who reported N fixation of approximately 350 kg ha^{-1} yr^{-1} in a glycine-Pangola mixture. Nevertheless, several authors agree that glycine nodulates more slowly than do other legumes, and has fewer nodulated plants and fewer nodules $plant^{-1}$ (Whiteman, 1972; and Philpotts, 1975). Other studies indicate that poor nodulation after direct drilling into a grass sward may be due to an allelopathic effect of some substance in the grass that inhibits nodulation (Philpotts, 1981).

Seed size varies with cultivar, but it ranges from 130,000 to 200,000 seeds kg^{-1} (Humphreys, 1980a). It has a high percentage of hard seed, therefore scarification is necessary. Several methods of scarification have been used with glycine. Neme (1966 and 1968) observed that germination increased from less than 25% for non-scarified seed to 70% following mechanical scarification. Other methods of scarification cited by Skerman (1977) include (1) concentrated sulphuric acid treatment for 25 min, drain and wash the seed thoroughly in water, and dry, and (2) immersion in boiling water for 1 min.

Glycine can be broadcast or planted in rows. Seeding rates range from 2.5 to 5.0 kg ha^{-1} (Humphreys, 1980a), and seeds should be planted at 1- to 2-cm depths. In Brazil, pure stands of glycine were sown at a rate of 2.5 kg ha^{-1} in rows that were 0.5 m apart (Skerman, 1977).

Glycine must be allowed to become established and to cover the ground before animals graze the pasture. Gartner and Fisher (1966) recommended that in the first year, the pasture be grazed as often as necessary to remove the grass canopy and allow light to reach the legume, but cattle should not graze the young glycine seedlings, and weeds should be carefully controlled. By the second year, glycine should be well established. They also recommended that pastures be grazed

rotationally in the warm wet months when growth is fast, and grazed continuously in winter in frost free environments. If the pasture is to be conserved for winter grazing, it can be grazed lightly in summer and spelled during autumn.

Glycine is a valuable pasture (Kyneur, 1960) and makes good hay and silage (Humphreys, 1980a). Lopez et al. (1981) reported average glycine DM yields in pure stands of 5.9 Mg ha^{-1} under simulated rotational grazing. Holder (1967) recorded CP from 129 to 202 g kg^{-1} DM and digestibility from 557 to 617 g kg^{-1} DM depending upon the stage of growth. Lopez et al. (1981) reported CP of 200 g kg^{-1} DM during the rainy season.

Association of Tropical Grasses and Legumes

In the tropics most beef and dairy cattle production systems are based entirely on forages. Animal production is often low due to several factors, such as low forage quality and low forage availability (Moore and Mott, 1973).

Growth of plants is probably limited more often by a deficiency of N than any other nutrient (Whiteman, 1980). Heavy N applications are required to produce high yields of grass with high CP concentration (Crowder and Chheda, 1982; and Salette, 1970). The favorable response of

forages to applied N in terms of increasing yield and CP is well known and documented. Crude protein concentration of Pangola increased from 49 g kg^{-1} DM before fertilization to 87 g kg^{-1} DM after a late season application of 110 kg ha^{-1} of N. In a second year the increase was from 37 to 72 g kg^{-1} DM (Minson, 1967).

An approach which may be more feasible in developing countries due to the high cost and low availability of fertilizer, is to incorporate legumes into grazing systems. Due to their ability to fix atmospheric N, legumes hold promise of being able to produce pasture of high quality for grazing cattle without N fertilization (Anon., 1976). Some research conducted in a temperate region has found (Erdelyi et al., 1987) that stands of pure legumes and mixed legumes-grasses without N yielded better than stands of pure grasses fertilized annually with 200 kg N ha^{-1}. Another advantage of legumes is their high CP concentration. Mature tropical grasses may have CP below 60 to 80 g kg^{-1} DM, and intake of animals grazing these forages may be reduced (Ventura et al., 1975). Minson and Milford (1967) concluded that intake of mature Pangola digitgrass was increased by adding 10 to 20% legume in the diet probably due to the elimination of CP deficiency. In addition, tropical legumes retain higher CP levels even in advanced stages of maturity (Milford and Haydock, 1965).

Anatomical and Physiological Differences

Tropical grasses and legumes are very different anatomically and physiologically in the way that they fix C, and this makes an association of the two rather difficult and challenging for the pasture manager (Humphreys and Jones, 1975). Mott (1981) stated that "...physiological differences between tropical grasses and legumes have important implications for legume-grass associations. Since their optima for light, temperature, and moisture differ, it is much more difficult to select compatible grasses and legumes in the tropics than among temperate species where the responses to environmental factors are similar" (p.36). Tropical grasses have a biochemical pathway of C fixation that is better adapted to the higher radiation and temperature conditions of the tropics; therefore, they have the potential of higher growth rates (Whiteman, 1980). This biochemical pathway was elucidated by Hatch and Slack (1966), and it is called the C-4 pathway because the first photosynthetic products are the 4-C malic and aspartic acids. It is different from the pathway originally demonstrated by Calvin and Benson (1948) in temperate species, called the C-3 pathway, because the first photosynthetic product in the pathway is a 3-C acid, phosphoglyceric acid.

The largest group of plants having the C-4 pathway are the tropical grasses in the subfamily Panicoideae, which includes Pangola digitgrass (Whiteman, 1980). Temperate grasses, tropical legumes, such as glycine, and temperate legumes have the C-3 pathway (Mott, 1981).

There are other differences associated with the C-fixing pathway that have important consequences in pasture productivity. These differences are summarized by Whiteman (1980) as the following:

(1) The CO_2 acceptor molecule in C-4 plants is phosphoenolpyruvate (PEP), and it is associated with the enzyme PEP-carboxylase that is highly reactive with CO_2. As a consequence, it is able to fix greater amounts of CO_2 than C-3 plants, where the CO_2 acceptor molecule is ribulose 1,5-bisphosphate (RuBP) and its associated enzyme RuBP-carboxylase.

(2) PEP-carboxylase is not inhibited by oxygen, but in contrast, RuBP-carboxylase is somewhat inhibited.

(3) Optimum temperature for PEP-carboxylase activity is between 30 and 35°C and for RuBP-carboxylase is between 20 and 25°C.

(4) Leaves in C-4 plants have two types of chloroplast containing cells, the bundle sheath cells surrounding the vascular tissue and the mesophyll cells surrounding the bundle sheath cells. In C-3 plants, there is only one type of chloroplast containing cell,

the chlorenchyma cell that is distributed throughout the leaf mesophyll.

(5) The physiological consequences are the following: (a) rate of photosynthesis is higher in C-4 plants than in C-3, (b) light saturation in C-4 plants is approximately at full sunlight, while in C-3 it is approximately at one-half full sunlight, (c) there is no apparent photorespiration in C-4 plants, and there is significant photorespiration in C-3 plants, (d) CO_2 compensation point is zero in the light for C-4 plants, while in C-3 plants it is about 37 mg kg^{-1} (Ludlow and Wilson, 1972).

The important consequence of these anatomical and physiological differences is that tropical grasses achieve up to three times the photosynthetic rate that tropical legumes do (Ludlow and Wilson, 1970). Tow (1967), under controlled environmental conditions, showed that the C-4 grass green panic (Panicum maximum Jacq. var. trichoglume) was much more productive at all light intensities and at higher root temperatures than the C-3 tropical legume, glycine. Due to their faster growth in tropical regions, C-4 grasses can dominate associations or even exclude the C-3 legume from the mixture; therefore, it is rather difficult to associate them with C-3 species. By contrast, in temperate regions associations have long been successful among C-3 grasses

and legumes where the responses to environmental factors are similar (Mott, 1981).

Establishment

Hard seed is characteristic of many tropical legumes, including glycine. It is a protection against false starts to the tropical wet season, and it is important in the regeneration of many pasture species (Gardener, 1975). Under natural conditions seeds are exposed to high temperatures, dry seasons, and other environmental factors that eventually scarify the seed and allow it to germinate. However, planting fresh-harvested seed can markedly reduce establishment because of hard seed, and seed scarification must be done. There are several scarification techniques, including mechanical, concentrated acid, dry-heat treatment, and hot water (Mott et al., 1982; Mott and McKeon, 1982; Gilbert and Shaw, 1979, Febles and Padilla, 1977; and Gray, 1962).

Advantages of including legumes in established grass swards have been manifested and are well documented (Monzote and Garcia, 1983; Kretschmer, 1970; Lopez et al., 1981; Mott, 1977; Shaw and Mannetje, 1970; and Partridge, 1975). But the success of using legumes in grazing systems will depend upon the ability to establish

a legume into a grass sward in a short period of time and with a simple method.

Monzote and Hernandez (1977) tested four sowing methods, (1) disk harrowing and broadcast sowing, (2) broadcast sowing and disk harrowing, (3) planting with a direct sowing machine, and (4) broadcast sowing, to oversow glycine into a Pangola digitgrass pasture. The authors mentioned that even though in the beginning of the trial there was a higher glycine percentage in treatments 1, 2, and 3, at the end of the trial all four methods showed similar performance. Therefore, they concluded that it is possible to overseed legumes into established pastures, and that the selection of the method depends upon the facilities available. This agrees with studies conducted by Gomes (1978) and McIvor (1983), where in the second year after establishment there was no difference among seedbed treatments. In Veracruz, Mexico, Garza et al., (1972) conducted a trial evaluating the establishment of three tropical legumes into a Pangola digitgrass pasture. Four soil preparation treatments, (1) plowing and harrowing, (2) plowing, (3) harrowing, and (4) burning, were evaluated. They concluded that there was no difference between treatments 1, 2, and 3, but that these treatments were better ($P<0.05$) than burning. Nevertheless, burning was the most economical treatment. Also, Thomson et al. (1983)

mentioned that legumes were established on burnt areas with no further treatments. Monzote et al. (1982) was able to successfully establish five tropical legumes into an existing Pangola digitgrass pasture with minimum tillage (harrowing twice). Glycine and 'Siratro' (Macroptilium atropurpureum [DC.] Urb.) had the best performance, contributing 88 and 80% of pasture biomass 6 months after planting.

Another approach to establishing perennial legumes is by using chemical weed control. Sistachs et al. (1977) studied the effect of three herbicides in the establishment of glycine. They concluded that the use of the incorporated preemergence herbicide trifluralin gave the best control of weeds and highest ($P<0.01$) DM yield. In another establishment study with herbicides, Canudas (1984) found that rhizoma peanut (Arachis glabrata Benth.) yield was approximately doubled, relative to an untreated area, if weeds were controlled. Grassy weeds are highly detrimental to the establishment of tropical legumes, but they can be effectively controlled without harming the legume by using selective herbicides, such as sethoxydim (Canudas, 1984; and Canudas et al., 1984).

Grazing Management

There has been a great deal of controversy about grazing management research, and whether fixed or variable (put-and-take) stocking rates should be used in grazing trials (Matches, 1987). Wheeler et al. (1973) reviewed this subject, and concluded that pasture experiments can be grazed using either variable or fixed stocking rates. They described criteria for choosing between these two methods. These included pattern of forage growth, possibility of harvest and storage of excess forage, and flexibility to accommodate changes in animal number.

Grazing management implies a degree of control over both the animal and the sward. Continuous and rotational grazing represent two extremes in grazing management (Matches and Burns, 1985). Hodgson (1979) defined rotational grazing as the practice of imposing a regular sequence of grazing and rest from grazing upon a series of grazing areas, and continuous grazing as the practice of allowing animals unrestricted access to an area of land for the whole or a substantial part of a grazing season. Mueller and Green (1987) described another grazing system called controlled grazing, that uses both continuous and rotational grazing management in a flexible system that can cope with changes in pasture

quantity and quality, according to animal requirements. Unlike rotational grazing, resting and grazing periods are never rigidly fixed for extended periods, and unlike continuous grazing, the grazing is never continuous year around.

In a study conducted by Stobbs (1969b) in Africa, continuous grazing and three- and six-paddock rotational grazing systems were compared. He found that animal production was slightly higher in the three-paddock rotation than in the continuous (1577 and 1493 kg ha^{-1}, respectively); however, the six-paddock rotation had lower animal production (1338 kg ha^{-1}). Grof and Harding (1970) reported that animals on rotationally grazed pastures had 16% higher liveweight gains over 2 years than those on continuous (1075 and 935 kg ha^{-1}, respectively) in a guineagrass (P. maximum Jacq.) and centro pasture with a stocking rate of 3.5 head ha^{-1}. Test (1987) in a study with three grazing systems (continuous, rotationally deferred, and short-duration rotation) did not find large differences in herbage production. Conway (1970) reported that in order to obtain an advantage of rotational grazing over continuous, higher stocking rates needed to be used on the rotationally grazed pastures. Low stocking rate rotational grazing gave lower liveweight gain per animal than continuous.

Another aspect of grazing management is the effect that it has upon the botanical composition. Tergas (1975) stated that under continuous grazing it was difficult to maintain the legume in the pasture because their recovery from grazing was slower than that of grasses. Gartner and Fisher (1966) mentioned that for a perennial grass-legume pasture, rotational grazing was generally desirable in warm and wet months, when growth was fast, but continuous grazing was possible in dry and colder months when growth was slow.

Whiteman (1969) indicated that frequent defoliations, whether by grazing or by mowing, reduced the yield and persistence of tropical legumes. This agrees with Jones (1979), and Bryan and Evans (1973), who observed that climbing legumes were favored by light grazing and long intervals between grazing periods, and with Humphreys (1980b) who suggested that twining legumes are not resistant to heavy grazing and rarely persist in humid environments where the year-around stocking rate exceeds 2.5 head ha^{-1}.

Stocking rate is an important factor affecting legume content of a mixed grass-legume pasture. Glycine percentage declined from 70 to 15% of the total biomass when the stocking rate increased from 1 to 2.5 cows ha^{-1} (Anon., 1976). Cowan et al. (1975) concluded that legume content of the pasture declines linearly ($P<0.05$) with

increasing stocking rate. In contrast, Stobbs (1969a) in a 3-year grazing study with stocking rates of 1.65, 2.5, and 5.0 head ha^{-1} found that the legume Stylosanthes gracilis H.B.K. was better able to withstand heavy grazing. Shaw (1978) also found that the yield of Stylosanthes humilis H.B.K. was strongly increased by high stocking rates, and suggested that this response may be explained by the reduction in competition from the native pasture. Santillan (1983) cited four different experiments conducted in Ecuador that showed that guineagrass-centro and guineagrass-glycine pastures were very persistent and productive mixtures even if heavy grazing pressures were used. Furthermore, when four stocking rates (2.7, 3.6, 4.8, and 6.3 head ha^{-1}) were imposed over 6 years of grazing on a pasture mixture of three grasses and five legumes, Rika et al. (1981) found that botanical composition was largely independent of stocking rate.

Bryan and Evans (1973) studied the effect of three stocking rates, 1.23, 1.65, and 2.47 head ha^{-1}, in a pasture planted with a mixture of five legumes and four grasses. They concluded that although stocking rate had a marked effect on botanical composition, more attention should be paid to the growth habit and life cycle of the legumes, because high stocking rate treatments favored prostrate legumes, while low stocking rates favored the

trailing ones. Both groups of legumes were a relative failure under the medium stocking rate treatment.

Forage Quantity and Quality

Evaluating forages requires measurements of both quantity and quality of forage. Yield of animal product per area is determined by the quantity and quality of forage consumed (Mott and Moore, 1985). Specifically, animal production area^{-1} is equal to number of animals area^{-1} (quantity aspect) times the gain animal^{-1} (quality aspect). The efficiency of forage utilization by livestock will depend upon quantity and quality.

Productivity

Forage production in grazing studies has been expressed in several ways, such as forage yield (Mott and Moore, 1985), yield on offer (Eng et al., 1978), herbage yield (Harris, 1978), pasture yield (Blunt, 1978), or herbage accumulation and consumption (Hodgson, 1979). Nevertheless, the definitions of these terms are not always clear, particularly as used in the literature.
Mott and Moore (1985) defined forage yield as the portion of the forage production that is consumed by the animal. This use of forage yield and production is analogous to

Hodgson's (1979) terms herbage consumption and accumulation, respectively. Nevertheless, most authors do not explain how they are defining herbage or pasture yield. As a consequence, there is much confusion, and it is hard to interpret the results of many grazing studies. Confusion is increased because some terms have acquired several meanings, some concepts have several names, and some are used incorrectly even though their true meanings are established (Thomas, 1980). Several attempts have been made to unify and clarify the meaning of terms used to describe the biological processes in grazing systems (Thomas, 1980; and Hodgson, 1979). Hodgson (1979) suggested that the term "yield" is not an acceptable one and that it is better to avoid it altogether, and instead to use herbage mass, consumption, or accumulation.

In a 2-year study, the effect of stocking rate on steer performance and pasture yield was measured on a Pangola digitgrass pasture (Blunt, 1978). He concluded that pasture yield declined linearly with increasing stocking rate. This agrees with results from a 5-year grazing study (Jones, 1979) and with Harris (1978) who in a review article cited several studies indicating that more intensive defoliation resulted in reduction of herbage DM yield. These conclusions need to be carefully analyzed because "yield" could have several interpretations. There is no doubt that as stocking rate

increases, herbage mass decreases, but there is some degree of uncertainty as to what the response of herbage consumption and accumulation would be. There has been a general agreement with Mott (1960) that as stocking rate increases, animal production ha^{-1} also increases up to a point after which production falls abruptly (Creek, 1970). It seems logical that during the phase when animal production ha^{-1} is increasing, herbage accumulation and consumption should be greater in order to maintain a higher number of animals. Perhaps, little utilization of the pasture has as a consequence low photosynthetic activity or higher rate of death and decay of plant material.

Nutritive Value

The nutritive value of a forage refers to its chemical composition, digestibility, and the nature of digested products (Mott and Moore, 1985; and Crowder and Chheda, 1982). The most reliable measure of forage quality was defined by Mott (1959) as the output per animal or animal performance (average daily gain or milk production). Nevertheless, alternative methods to estimate forage quality are needed by researchers when it is not possible to conduct long-term production trials (Moore, 1981). An alternative definition of forage

quality is the voluntary intake of digestible energy (Moore, 1980), or voluntary intake of digestible organic matter (Minson, 1980; as cited by Moore, 1981). Laboratory methods for estimating forage nutritive value, such as CP and IVDOM, are very useful methods for comparing large numbers of samples, but these values provide only an estimation of nutritive value, and no practical recommendations should be made before making appropriate correlations with animal performance. Duble et al. (1971) found that IVDDM was significantly correlated (r=0.78) with animal performance on six perennial summer grasses. McLeod and Minson (1969) concluded that in vitro digestibilities of grasses, legumes, and grass-legume mixtures were closely related to the in vivo digestibilities. The standard errors and correlation coefficients of these three regressions were 0.6, 0.6, and 1.5, and 0.998, 0.994, 0.987, respectively.

Crude protein is the most common chemical component measured in plant assessment studies. Research has indicated that digestible CP (DCP) can be predicted with a linear equation (DCP=0.89*CP-3.25) from CP values obtained from laboratory analyses (Milford and Minson, 1965a). Critical levels of CP depend on the type of forage. Milford and Minson (1965b) indicate that there is a positive correlation between voluntary intake of D. decumbens and CP concentration when CP is less than 70 g

kg^{-1} DM; therefore, intake declines rapidly when CP of the consumed feed is below 70 g kg^{-1} DM. Minson (1967) found 54% higher intake of Pangola digitgrass when CP was 72 g kg^{-1} DM than when it was 37 g kg^{-1} DM.

There is a continuous change in quality as plants mature and pass through different physiological stages. De Carvalho (1976) reported a high negative correlation (r=-0.98) between IVDOM and age for D. decumbens, with IVDOM ranging from 730 g kg^{-1} OM in week 1 to 360 g kg^{-1} OM in week 22. For three breeder lines of D. decumbens, he reported correlation coefficients between CP and age of -0.88, -0.95, and -0.96, which averaged over lines corresponds to a CP decrease from 200 g kg^{-1} DM in week 1 to 45 g kg^{-1} DM in week 22.

The livestock producer needs to understand the factors that affect forage quality and quantity in order to make wise grazing management and forage utilization decisions (Moore, 1980).

Animal Production

The value of a pasture is determined by animal production (Whiteman, 1980). Animal production ha^{-1} is a function of product $animal^{-1}$ and number of animals ha^{-1} (Mott and Moore, 1985). Stocking rate is the dominant factor affecting production ha^{-1} (Wheeler, 1962), but the

quality aspect of the pasture also plays a very important role in determining animal production. Conway (1965) studied the performance of beef cattle at three intensities of stocking. It was found that increasing stocking rate from 2.5 to 4.3 head ha^{-1} increased liveweight gain ha^{-1}, but increasing the stocking rate further to 6.2 head ha^{-1} reduced liveweight gain ha^{-1}. Evans (1970) in a beef production study with stocking rates of 1.23, 1.65, and 2.47 head ha^{-1} found that increasing stocking rate increased the 3-year average of liveweight gain ha^{-1} (295, 326, and 384 kg ha^{-1}, respectively).

Milk Production

Blydenstein et al. (1969) concluded that acceptable levels of milk production from Pangola digitgrass in a humid tropical environment are possible under intensive management. The management consisted of pasture fertilization and concentrate supplementation to the cows. They obtained 6000 kg ha^{-1} yr^{-1} of milk with a high conversion efficiency from the fertilization and concentrate. Cubillos (1975) measured milk production from commercial herds of 70 to 100 cows in Turrialba, Costa Rica. The annual mean milk production on guineagrass, Pangola digitgrass, and stargrass (Cynodon

nlemfuensis Vanderyst) were very similar (6.9, 6.9, and 6.0 kg cow^{-1} d^{-1}, respectively); nevertheless, the milk production ha^{-1} was 7.3, 16.5, and 32.5 kg d^{-1}, respectively, due to the differences in carrying capacity. The author mentioned that 90 to 92% of the milk production was attributed to the grass and the rest to low levels of concentrate and sugarcane molasses supplementation.

Stobbs and Thompson (1975), and Hamilton et al. (1970), stated that the principal cause of low milk production from tropical pastures was the reduced intake of digestible nutrients, particularly energy. A feasible approach to increase the intake of digestible nutrients from tropical pasture is to include legumes in the diet. Minson and Milford (1967) concluded that voluntary intake of Pangola digitgrass plus legume was increased as the percentage of the legume in the diet increased. In Queensland, Australia, glycine demonstrated potential to increase milk production. Milk production with a stocking rate of one cow ha^{-1} was 4000 kg cow^{-1} over a 300-d lactation (Anon., 1976). This milk production agrees with Cowan et al. (1974), who reported a 6-year average of 4100 kg for Friesian cows grazing a green panic-glycine association without any other supplementation. In Bolivia, Paterson et al. (1981) found an increase of 11 to 20% in milk production, when

dairy cows grazed a 4-ha pasture of Hyparrhenia rufa (C.G. Nees) Stapf with 1 ha associated with glycine and Macrotyloma axillare cv. Archer, compared with a 4-ha pasture of grass alone. Cowan et al. (1975) concluded from a 2-year experiment in a green panic-glycine pasture, that "...per hectare milk production from tropical grass-legume pastures can approach that from temperate pastures and that energy supplementation early in lactation would substantially increase per cow production" (p.740).

Beef Production

Several experiments indicate that including legumes in grass swards increases liveweight gain of beef cattle. Norman (1970) found a positive linear relationship (R^2 = 0.72) between the amount of S. humilis in the diet and liveweight gain (kg head^{-1}). Garza et al. (1978) compared Pangola digitgrass alone and associated with glycine in Veracruz, Mexico. Gain ha^{-1} and average daily gain during a 12-month grazing period on Pangola-glycine was higher ($P<0.05$; 642 and 0.54 kg, respectively) than on Pangola alone (468 and 0.39 kg, respectively). In a 2-year study conducted in Bolivia, Paterson and Horrell (1981) found that when glycine was associated with P. maximum cv. Petrie gain ha^{-1} increased from 91 to 181 kg,

and average daily gain increased from 0.16 to 0.40 kg during a 6-month dry period. Evans and Bryan (1973) conducted an animal production experiment over a 6-year period in a grass-legume pasture with three stocking rates (1.23, 1.65, 2.47 head ha^{-1}). The increase in stocking rate resulted in an increase in production ha^{-1} and a decrease in production $animal^{-1}$. They also found a positive correlation ($P<0.01$, $r=0.89$) between legume content and liveweight gain $head^{-1}$.

Present levels of animal production on tropical pastures are low (Mannetje, 1978); therefore, there has been an increasing interest in pasture improvement in the region. Much of the present research in tropical regions is directed toward a low-input philosophy. Within the context of low inputs, the application of synthetic N fertilizers is not economical. Biological N fixation through legumes in symbiosis with rhizobia is therefore an essential low-input strategy (Toledo, 1985). Thus, improved and well-managed tropical grass and legume pastures have great potential in helping agriculture to meet the increasing demand for food worldwide.

MATERIALS AND METHODS

This research was conducted at "La Posta" Animal Experimental Station of the National Institute of Forestry, Agronomy, and Animal Science of Mexico. The station is located approximately 22.5 km south of the port of Veracruz, Veracruz, Mexico at 19°N latitude and 96°W longitude. The vegetation of this region is classified as low deciduous forest, with the characteristic feature being that most trees shed their leaves during the dry season (Flores et al., 1971). The area is used mainly for beef cattle grazing and has a rolling topography with altitudes that range from 10 to 16 m above sea level. The average minimum and maximum temperatures are 19 and 31°C, respectively, and the mean annual temperature is 25°C (Fig. 1). Annual precipitation is approximately 1750 mm in a well-defined rainy season from June to November. During this time about 90% of the total rainfall is received (Fig. 2). Mean annual relative humidity is approximately 82% (SARH, 1986). Soils in the region have sandy loam to sandy clay loam textures, are of slightly acid pH, and have a low to moderate percentage of organic matter.

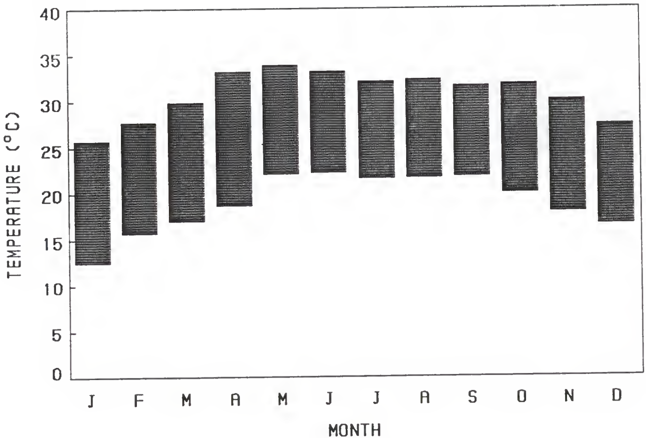

Fig. 1. Mean maximum and minimum temperatures recorded at "La Posta" during 1984 to 1986.

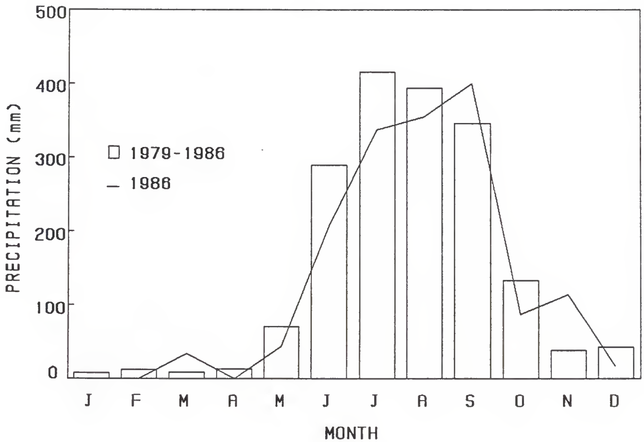

Fig. 2. Precipitation recorded at "La Posta".

Table 1 shows the soil analyses of samples taken at the experimental area.

Experimental Site

The 1-ha area selected for the experiment had been established with Pangola digitgrass and 'Clarence' glycine for over 14 years. Throughout the years, the percentage of glycine in the herbage mass declined substantially, perhaps due to inadequate grazing management. In order to conduct the experiment, the existing herbage mass was harvested, and the land was prepared for planting with a 2-m wide subsoil plow (60 cm deep). The area was fertilized with 25 kg ha^{-1} of P and small-disk harrowed. The Clarence glycine was manually over-seeded in rows (2-m apart) made by subsoiling on 2 Dec. 1985. The planting rate was 3 kg ha^{-1} of seed scarified with hot water (5 min at 95°C), and it was not inoculated because it was being planted in an area with some established glycine. The experimental area was irrigated during the establishment period (Dec. 1985 to May 1986) because it occurred during the dry season.

Table 1. Soil analyses of samples taken at a depth of 0 to 30 cm in the experimental area.

TEXTURE:	SANDY LOAM (71.5% sand) (13.8% clay) (14.7% silt)
COLOR:	DARK BROWN (10 yr 3/3)
pH:	6.15 (slightly acid)
Organic matter (%)	2.5
Element:	
Total nitrogen (%)	0.234
Phosphorus† (ppm)	1.5 (EP)
Potassium (ppm)	230.5 (ER)
Calcium (ppm)	1405.0 (ER)
Magnesium (ppm)	312.5 (ER)

†extracted by the PEECH method.
EP=extremely poor.
ER=extremely rich.

Pasture Layout

The 1-ha area was divided in May 1986 into 24 experimental pasture units of 400 m^2 (Fig. 3). Each pasture unit was divided with a permanent three-wire fence, the middle wire being electrified. A water line was buried along the middle of the experimental area from which garden hoses were connected to fill the 100-L water tanks in each pasture.

Experimental Variables and Design

The experimental variables were 1) three levels of residual dry matter (RDM) after grazing, 2, 4, and 6 Mg ha^{-1}, and 2) four lengths of grazing cycle, continuous, 21, 42, and 63 d. Residual DM decisions were based on live DM herbage mass (pangola digitgrass, glycine, and weed). Dead DM herbage mass was not included because it was not considered to be an important part of the animals' diet. The grazing period was constant (4 d) in all grazing cycles of the rotationally grazed treatments. Treatment combinations (Table 2) were randomly allocated to each experimental pasture.

The design used was a randomized complete block with a factorial set of treatments. The experiment was replicated twice. The complete model was expected to be

Fig. 3. Aerial photograph of the experimental area.

Table 2. Treatment combinations and assignments to pastures.

Pasture No.	RDM† (Mg ha^{-1})	GC‡ (d)	No. cycles	No. Blocks	Size of Exp. Pasture (m^2)
10, 12	2	Cont.§	5	2	400
9, 19	2	21	8	2	400
5, 11	2	42	4	2	400
2, 4	2	63	3	2	400
8, 14	4	Cont.	5	2	400
6, 18	4	21	8	2	400
1, 20	4	42	4	2	400
21, 23	4	63	3	2	400
7, 17	6	Cont.	5	2	400
3, 13	6	21	8	2	400
16, 24	6	42	4	2	400
15, 22	6	63	3	2	400

†RDM = residual dry matter after grazing.
‡GC = grazing cycle (rest period + 4 d of grazing).
§Cont.= continuous grazing (0 d rest).

a second order polynomial response-surface, but only those effects which explained a significant portion of the variation in a given response variable were included in the final model. The complete model is written as follows:

$$y = \beta_0 + \beta_1 RDM + \beta_2 GC + \beta_3 RDM^2 + \beta_4 GC^2 + \beta_5 RDMxGC + \epsilon$$

where, y is the estimated response of any parameter,

RDM is the residual dry matter,

GC is the grazing cycle,

β_0 is the intercept,

β_1 and β_2 are the linear coefficients for RDM and GC, respectively,

β_3 and β_4 are the quadratic coefficients for RDM and GC, respectively,

β_5 is the cross-product coefficient for RDM and GC, and

ϵ is the experimental error.

RDM is subject to measurement error, and it is impossible to obtain the exact RDM after each grazing period. In the regression analysis the actual RDM obtained after grazing was used.

Grazing Procedure

Twenty-five Holstein-Zebu cross heifers, weighing approximately 300 kg each, supplied the pool of animals used to graze the experimental pastures. In addition there was a group of 20 Holstein-Zebu cross dry cows, weighing approximately 450 kg each, that were used if extra animals were needed. The animals were used to impose the effect of grazing on pasture productivity, botanical composition, and other response variables. The objective of the research was only to evaluate the effect of the animal on pasture performance; thus no animal data were taken. When the animals were not grazing the experimental pastures, they were maintained in Pangola digitgrass pastures adjacent to the experiment.

The procedure for determining the number of animals to be put on a given pasture was the following. A visual estimation was made of live pregraze herbage mass in Mg DM ha^{-1}. They were constantly compared to the actual herbage mass after harvested samples were dried, in order to calibrate the eye and correct the visual estimations. Animal number per pasture were calculated using the visual estimate and the following equation.

$$NA = \frac{(HM - RDM) * 40}{EDMI * GP} \qquad \text{Eq. 1}$$

where, NA = number of animals

HM = live pregraze herbage mass (visual estimate in Mg DM ha^{-1}),

RDM = target residual DM (Mg ha^{-1}),

40 = factor to convert Mg ha^{-1} to kg per 400 m^2,

EDMI= 8 kg d^{-1} was the estimated DM intake of 300 kg grazing animal, and

GP = 4 d grazing period, was kept constant.

During the grazing period the number of animals could be adjusted if, for any reason, it was suspected that the target RDM would not be achieved.

The management of the continuous treatment (rest interval=0) was different. It was impossible to maintain one or two animals on the pastures at all times; therefore, this treatment was actually a simulation of continuous grazing. The objective for this treatment was to maintain the target RDM; therefore, animals were put on and taken off each week in order to achieve this objective.

Response Variables and Measurement Procedures

The experiment was conducted from June to November of 1986. Experimental pastures were homogenous at the

beginning of the experiment, and all RDM treatments within a block were imposed at the same time. During the first week, all pastures of block 1 were sampled before grazing (Monday) and after grazing (Friday), and during the second week, all pastures of block 2 were sampled in a similar manner. The initial defoliation was considered to be a staging of the pasture, and the responses reported in the results section do not include data from this grazing. Subsequent pregraze and postgraze sampling was conducted depending upon the GC treatment, except for continuously grazed pastures which were sampled every 28 d (Table 3).

Total herbage mass (live and dead) was determined at five, 0.25-m^2 representative sites per experimental pasture before and after each grazing. The samples were harvested with machetes by skilled persons. First they cut around the edge of the 0.25 m^2 wire hoop, then the hoop was removed and the site was cut to ground level. For the continuous treatment, due to the fact that animals were put in and taken out regularly, 1-m^2 round, portable, exclusion cages were used to restrict animal access, and 0.25 m^2 areas from inside the cages were clipped to estimate forage accumulation and consumption. The total herbage mass determination was made every 28 d in caged and uncaged sites using the paired sampling method as described by Klingman (1943). This method

Table 3. Sampling schedule for the whole experimental period.

	DATE																							
	J23	J30	J7	J14	J21	J28	A4	A11	A18	A25	S1	S8	S15	S22	S29	O6	O13	O20	O27	N3	N10	N17	N24	D1
	WEEK[+]																							
GC-RDM[‡]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	block number																							
0[§]-2	1	2			1	2			1	2			1	2			1	2			1	2		
0 -4	1	2			1	2			1	2			1	2			1	2			1	2		
0 -6	1	2			1	2			1	2			1	2			1	2			1	2		
21-2	1	2		1	2		1	2		1	2		1	2		1	2		1	2		1	2	
21-4	1	2		1	2		1	2		1	2		1	2		1	2		1	2		1	2	
21-6	1	2		1	2		1	2		1	2		1	2		1	2		1	2		1	2	
42-2	1	2					1	2					1	2					1	2				
42-4	1	2					1	2					1	2					1	2				
42-6	1	2					1	2					1	2					1	2				
63-2	1	2								1	2								1	2				
63-4	1	2								1	2								1	2				
63-6	1	2								1	2								1	2				

[+]pregraze and postgraze samples taken each week as indicated for the appropriate block and treatment combination.

[‡]GC = grazing cycle (rest period + 4 d of grazing), and RDM = residual dry matter (Mg ha^{-1}).

[§]0= continuous grazing (0 d rest).

consists of selecting one site at random and a second site as similar to the first in live herbage mass and botanical composition as possible. The cage is then randomly assigned to one site, and the other one is identified with a painted stake. Then every 28 d total herbage mass is determined for the paired sample sites. The inside-cage measurement is comparable to before grazing and outside the cage to after grazing. Three cages were used per experimental pasture, and they were relocated at different sites every 28-d period.

The total herbage mass sample was collected in a numbered cloth bag. All bags were taken to the laboratory and placed immediately in a refrigerator while hand separations were completed. Samples were separated into Pangola digitgrass, glycine, weeds, and dead matter. Individual components were placed in bags and dried at 65°C. Forty-eight to 72 h later they were weighed and each component was estimated.

The response variables were the following:

(1) Total herbage mass

- Live herbage mass
- Dead herbage mass

(2) Botanical composition

- Pangola digitgrass percentage
- glycine percentage
- weeds percentage

(3) Dry matter accumulation

(4) Dry matter consumption

(5) Growth rate

(6) Nutritive value

- crude protein
- in vitro digestible organic matter

Total herbage mass was separated into live herbage mass (Pangola grass, glycine, and weeds) and dead herbage mass (any decayed or dead plant material). Live herbage mass is mean live pregraze DM herbage mass over cycles, and dead herbage mass is mean dead pregraze DM herbage mass over cycles. The number of cycles depends on the GC treatment. There were eight, four, and three cycles for the GC levels 21, 42, and 63 d, respectively. Continuously grazed pastures were sampled five times.

Botanical composition was determined by hand separations of the pregraze herbage mass sample into Pangola digitgrass, glycine, and weeds. Weeds were any broadleaf plant, legume other than glycine, or grass other than Pangola. These data were used to obtain the percentage of Pangola, glycine, and weeds (Eq. 2 to 4). Dead herbage was not used in the calculation of botanical composition, but it was statistically analyzed as a separate response variable.

$$\text{Pangola percentage} = \frac{P}{HM} \times 100 \qquad \text{Eq. 2}$$

$$\text{Glycine percentage} = \frac{G}{HM} \times 100 \qquad \text{Eq. 3}$$

$$\text{Weed percentage} = \frac{W}{HM} \times 100 \qquad \text{Eq. 4}$$

where, P= dry weight (Mg ha^{-1}) of pangola,

G= dry weight (Mg ha^{-1}) of glycine,

W= dry weight (Mg ha^{-1}) of weeds, and

HM= live pregraze DM herbage mass (Mg ha^{-1}).

Dry matter accumulation is the difference between live herbage mass after grazing and live herbage mass before grazing of the next cycle (Eq. 5). Total DM accumulation is the sum over cycles (Eq. 6), and does not include the DM accumulated during the establishment period.

$$DMA_i = B_i - A_{(i-1)} \qquad \text{Eq. 5}$$

$$TDMA = \sum_{n}^{c_i} [B_i - A_{(i-1)}] \qquad \text{Eq. 6}$$

where, DMA_i= dry matter accumulation (Mg ha^{-1}) of cycle i,

TDMA= total DMA (Mg ha^{-1}),

$A_{(i-1)}$= herbage mass after grazing (Mg ha^{-1}) of cycle i-1,

B_i= herbage mass before grazing (Mg ha^{-1}) of cycle i,

c= grazing cycles,

i= cycle number (i=2,3,...,n), and

n= number of cycles for a given treatment.

Dry matter consumption is the difference between live herbage mass before and after grazing of the same cycle (Eq. 7). Total DM consumption is the sum over cycles (Eq. 8), but does not include DM consumption of cycle 1 (staging) because that would bias the results in favor of the lower RDM treatments.

$$DMC_i = B_i - A_i \qquad \text{Eq. 7}$$

$$TDMC = \sum_{n}^{c_i} (B_i - A_i) \qquad \text{Eq. 8}$$

where, DMC_i= dry matter consumption (Mg ha^{-1}) of cycle i,

TDMC= total DMC (Mg ha^{-1}),

A_i= herbage mass after grazing (Mg ha^{-1}) of cycle i,

B_i, c, i, and n as in Eq. 6.

Growth rate was estimated by dividing total DM accumulation by the sum of rest intervals (Eq. 9). The grazing period was kept constant (4 d), and it was assumed that there was no growth during the grazing period. For the continuous treatments there was not a grazing cycle, therefore growth rate was estimated by dividing DMA by 28-d rest period.

$$GR = \frac{TDMA * 100}{(GC-4) * n} \qquad \text{Eq. 9}$$

where, GR= growth rate (g m^2 d^{-1}) ,

100= factor to convert Mg ha^{-1} to g m^2,

GC= grazing cycle minus grazing period of 4 d,

TDMA and n as in Eq. 6.

Laboratory and Statistical Analyses

Pangola, glycine, and weed components of each experimental pasture were ground to pass a 4-mm screen with a Wiley Mill™. The five samples of each component per pasture per cycle were mixed together and one sub-sample was taken. This sub-sample was then ground to pass a 1-mm screen in a Tecator Cyclotec® Sample Mill and analyzed at the Forage Evaluation Support Laboratory of the University of Florida for in vitro digestible organic matter (IVDOM) and N concentration. The IVDOM procedure

used was a modification of the two-stage technique (Moore and Mott, 1974), and includes 1) incubation of a sample with rumen microorganisms for 48 h followed by 2) 44 h incubation with acid-pepsin. The results express g of OM that were digested or disappeared per kg of OM. The N analysis was performed by a modification of the standard Kjeldahl procedure; therefore, the value represents total N. The samples were digested using a modification of the aluminum block digestion procedure of Gallaher et al. (1975), and analyses of digestate for ammonia were done using the Technicon Autoanalyzer™ II (Hambleton, 1977). The percentage crude protein (CP) was determined by multiplying the N percentage by 6.25, and the results express g of CP per kg of DM.

The response variables were analyzed statistically using the least squares method of the GLM procedure of the SAS Institute Inc. (1985). The graphs were plotted with EnerGraphics 2.0™ software from Enertronics Research, Inc.

RESULTS AND DISCUSSION

Relationship Between Actual and Target Residual Dry Matter

Mean actual and target levels of RDM after grazing were similar (Table 4). Nevertheless, there was some variation in the RDM of each grazing cycle (GC). Growth and defoliation patterns of the 21-, 42-, and 63-d GC treatments are presented in Figs. 4, 5, and 6, respectively. No figure is presented for the continuous treatment because live herbage mass was constantly maintained close to the target RDM; therefore, there were no extended periods of DM accumulation. Because there was variation between actual RDM and target RDM, actual RDM was used in the statistical analysis. The values for RDM were based on live herbage mass. Dead herbage mass was not included when determining the end point of grazing because it was not considered to be grazed by the animals. The regression analysis between the actual and target RDM is presented in Table A-1.

Table 4. Actual vs. target residual dry matter (RDM) after grazing by treatment combination.

Pasture No.	GC† (d)	Block No.	Target RDM (Mg ha^{-1})	Actual RDM‡ (Mg ha^{-1})
12	Cont.§	1	2	1.96
19	21	1	2	1.71
11	42	1	2	2.37
2	63	1	2	1.97
14	Cont.	1	4	3.80
18	21	1	4	4.20
20	42	1	4	4.13
21	63	1	4	4.09
17	Cont.	1	6	5.92
13	21	1	6	5.24
16	42	1	6	5.42
15	63	1	6	6.06
10	Cont.	2	2	1.76
9	21	2	2	1.93
5	42	2	2	1.83
4	63	2	2	2.18
8	Cont.	2	4	3.84
6	21	2	4	4.08
1	42	2	4	4.18
23	63	2	4	4.05
7	Cont.	2	6	5.21
3	21	2	6	5.54
24	42	2	6	6.04
22	63	2	6	5.58

†GC = grazing cycle (rest period + 4 d of grazing).
‡Mean over all grazing cycles.
§Cont.= continuous grazing (0 d rest).

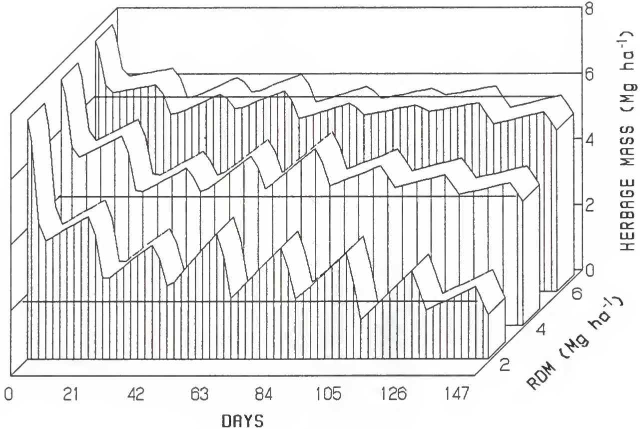

Fig. 4. Pregraze and postgraze live herbage mass over the season for the 21-d grazing cycle for each level of residual dry matter (RDM).

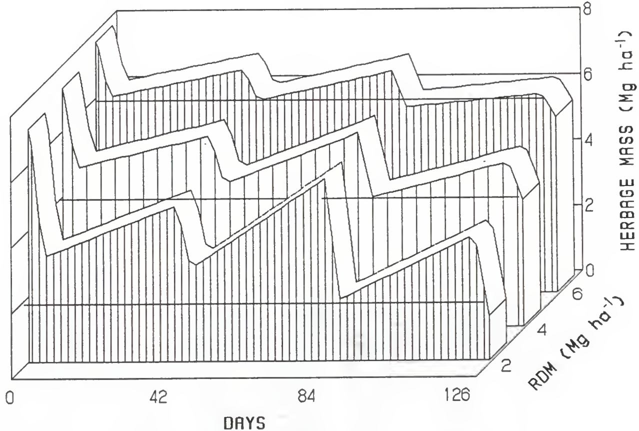

Fig. 5. Pregraze and postgraze live herbage mass over the season for the 42-d grazing cycle for each level of residual dry matter (RDM).

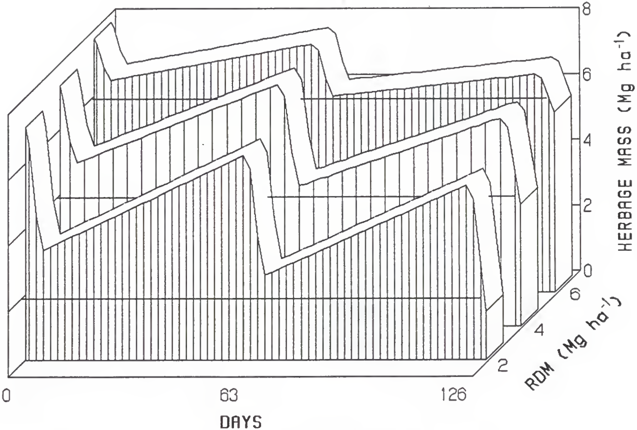

Fig. 6. Pregraze and postgraze live herbage mass over the season for the 63-d grazing cycle for each level of residual dry matter (RDM).

Effect of Residual Dry Matter and Length of Grazing Cycle on Mean Pregraze Herbage Mass

Live Herbage Mass

Mean live pregraze DM herbage mass over cycles, which in the following discussion will be referred to simply as live herbage mass, was composed of Pangola digitgrass, glycine, and weeds. This measurement was the instantaneous assessment of the amount of live herbage available before the grazing period started for the rotationally grazed pastures, and it was the amount outside the cage for the continuous treatments.

Residual DM and GC explained similar percentages of the variation in live herbage mass (47 and 46%, respectively; $P<0.01$). Live herbage mass decreased linearly (Fig. 7; Table A-2; $P<0.01$) as GC and RDM decreased (i.e. as the grazing intensity or stocking rate increased). Live herbage mass ranged from 2.1 to 7.3 Mg ha^{-1}. There was a RDM x GC interaction ($P<0.01$), which indicates differences in the slope of the effect of GC for each RDM. The regression analysis is presented in Table A-3. These results agree with Jones (1979) who conducted a grazing experiment with an association of Siratro and *Setaria anceps* cv. Nandi at Queensland. In this experiment, the author measured "pasture yield" once in each of the four grazing seasons during which the

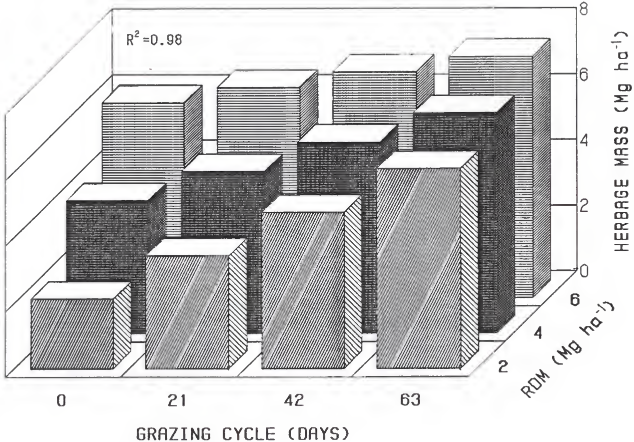

Fig. 7. Effect of grazing cycle and residual dry matter (RDM) upon live herbage mass.

experiment was conducted. He found that total yield decreased linearly ($P<0.01$) with increasing stocking rate and with increasing grazing frequency. It is unclear, however, what the author means by "yield", which based on his methodology appears to be herbage mass. Also, Blunt (1978) found that pasture yield declined linearly with increasing stocking rate (885 kg DM ha^{-1} for each unit increase in stocking rate). Sampling methodology was to take 10, 0.5-m^2 quadrats per paddock each 4 to 6 weeks. This measure of pasture yield also seems to be herbage mass. Rika et al. (1981) conducted an experiment on pasture production in Bali with four stocking rates. They sampled 1-m^2 randomly placed quadrats every 3 to 4 months and determined botanical composition and pasture DM on offer. Their conclusion was that the "amount and height of pasture on offer" were negatively related to stocking rate.

When conducting grazing trials, many researchers measure herbage mass at two or three times during the grazing season, but unfortunately these values are often confused by readers to be DM accumulation or consumption. Nevertheless, the only direct method to measure DM accumulation and consumption is by sampling before and after each grazing period or by using cages when pastures are grazed continuously.

Dead Herbage Mass

Mean dead pregraze DM herbage mass over cycles, which will be referred to simply as dead herbage mass, was composed of decayed or dead plant material. It was primarily influenced by RDM, which explained 72% of the variation in the response (Table A-4). Dead herbage mass decreased linearly ($P<0.01$) as RDM decreased, but there was an interaction of RDM x GC ($P=0.03$). At high RDM, GC had a greater effect on dead herbage mass than at low RDM. Dead herbage mass for the 63-d GC treatment ranged from 0.6 to 3.0 Mg ha^{-1} for the 2 and 6 Mg ha^{-1} RDM levels, respectively (Fig. 8; Table A-2). The higher amount of dead herbage mass for the higher RDM treatments appeared to result from the low utilization of the pasture.

Effect of Residual Dry Matter and Length of Grazing Cycle on Botanical Composition

Pangola Digitgrass Percentage

Pangola digitgrass percentage (based on live pregraze DM herbage mass) was influenced by RDM only, and this variable accounted for 71% of the variation (Table A-5). Percent digitgrass increased from 79% at the highest RDM level to 92% at the lowest (Fig. 9; Table

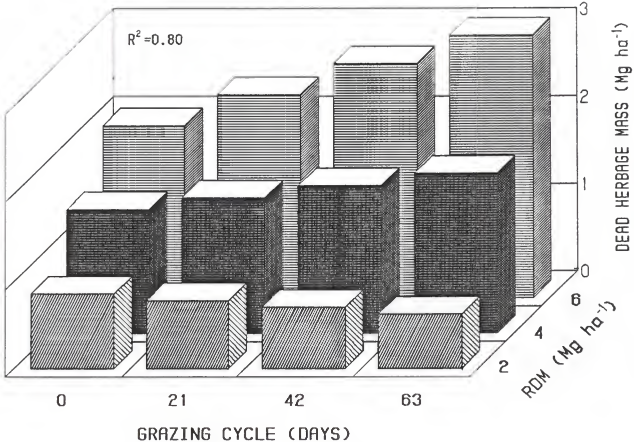

Fig. 8. Effect of grazing cycle and residual dry matter (RDM) upon dead herbage mass.

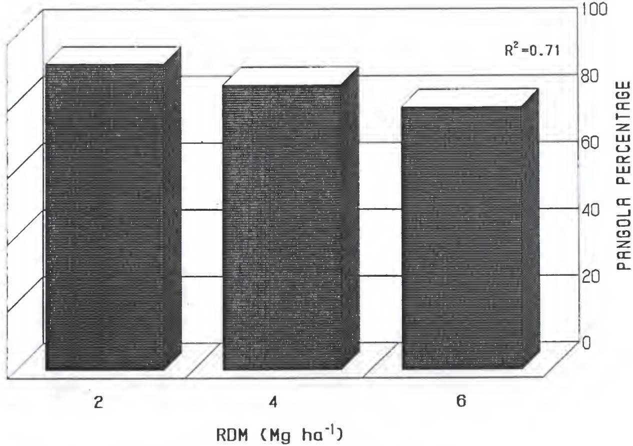

Fig. 9. Effect of residual dry matter (RDM) upon Pangola digitgrass percentage in live herbage mass.

A-2). There was a 3.4 percentage unit increase in Pangola for each Mg ha^{-1} decrease in RDM. Osbourn (1969), at the British Grassland Society meetings in London, mentioned that one of the outstanding characteristics of Pangola digitgrass was resistance to grazing. He said that Pangola digitgrass would tolerate both severe and lax grazing and, therefore, could be confidently distributed to livestock farmers. Also in a research with a complex pasture mixture (five legumes and four grasses), Bryan and Evans (1973) found that percentage Pangola increased markedly throughout the trial.

Glycine Percentage

In general, as glycine percentage (based on live pregraze DM herbage mass) decreased, Pangola digitgrass percentage increased, with no change in weed percentage. Glycine percentage decreased quadratically (P=0.03) at a decreasing rate as RDM decreased (P=0.03) and linearly as GC decreased (P=0.04; Table A-6), but the majority of the variation (75%) was explained by RDM. Glycine percentage (Fig. 10; Table A-2) in pregraze herbage mass ranged from 0% in the continuous treatment with low RDM, to 15% with the longest GC and the highest RDM. This response is similar to that observed by Jones (1979) in a study of

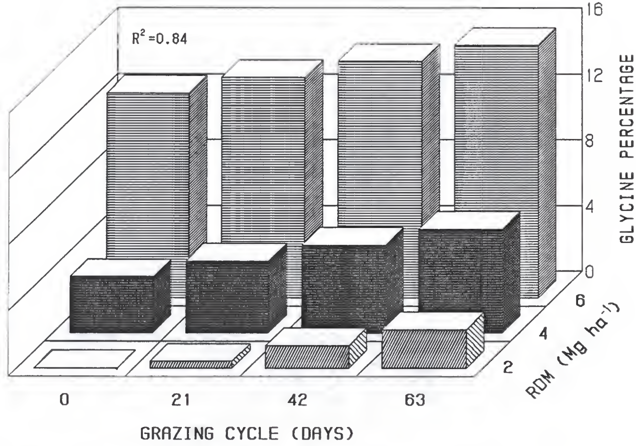

Fig. 10. Effect of grazing cycle and residual dry matter (RDM) upon glycine percentage in live herbage mass.

the effect of five stocking rates and three frequencies of grazing on a siratro-setaria pasture. He found a decrease in legume with higher stocking rates, but the decline was less marked in the longest grazing frequency. Cowan et al. (1975) imposed four stocking rates on a green panic-glycine pasture. They found that legume percentage of the pasture declined linearly ($P<0.05$) with increasing stocking rates.

Main factors causing legume decline in grazed pasture were discussed by Whiteman (1969). He mentioned that important factors affecting legume persistence include height of defoliation and the morphology of the species. Close defoliation tends to remove the major portion of the young active leaf material and terminal meristems, leading to a reduction in rate of recovery and ability to compete with the sown grass. Roberts (1980) suggested that overgrazing is a very common problem with twining tropical legume pastures. He added that they have excellent fattening capacity but comparatively low carrying capacity. In a recent study, Davison and Brown (1985) measured the effect of four management treatments upon a gatton panic (P. maximum Jacq.), glycine, and greenleaf desmodium (Desmodium intortum [Mill.] Urb.) pasture that had rapidly decreased in legume content after being stocked at 2 cows ha^{-1}. They concluded that destocking over summer or reducing the stocking rate

would lead to the recovery of twining legumes in previously overstocked pastures.

Weed Percentage

Mean weed percentage (based on live pregraze DM herbage mass) was 8.2, and it was mainly composed of vaseygrass (Paspalum urvillei Steud.; Fig. 11; Table A-2). The regression analysis is presented in Table A-7, but none of the experimental variables affected weed percentage. In addition, the low coefficient of determination (R^2 = 0.20) indicates that there was no relationship between the experimental variables and this response. Nevertheless, in the field it appeared that the lowest RDM had a higher number of weed plants, but they were being consumed and were kept grazed close to the ground level. In contrast, the highest RDM had fewer weeds, but the weeds were larger because they were not being consumed. When the data were analyzed as percentage of the herbage mass, a high number of small weeds was equivalent to a lower number of larger weeds. There were no data taken on number of weeds per area, so these conclusions are based solely on field observations. However, it is expected that if the experiment were conducted another year, the weed population in the lowest

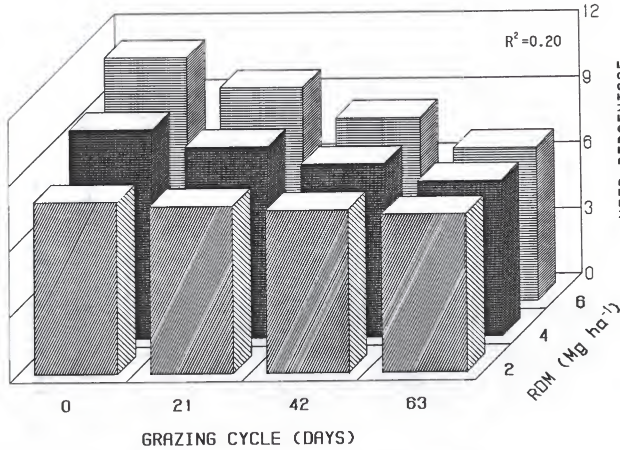

Fig. 11. Effect of grazing cycle and residual dry matter (RDM) upon weed percentage in live herbage mass.

RDM may have increased at a faster rate than for the other RDM levels.

Several authors (Stobbs, 1969a; and Bryan and Evans, 1973) have reported that weed percentage increased as a result of high stocking rates. Invasion by inferior species at high stocking rates can be of economic importance because weeds can have serious detrimental effects on animal production (Roberts, 1980). He also mentioned that the correlation between changes in botanical composition and animal production is too obvious and consistent to be ignored.

Overall, the experimental variable that had the most effect on botanical composition was RDM. This agrees with the majority of grazing experiments conducted with different levels of stocking rate or grazing pressure (Eng et al., 1978; Roberts, 1980; and Bryan and Evans, 1973). This is one reason why stocking rate is generally recognized as the main factor that can influence animal production (Conway, 1970).

Effect of Residual Dry Matter and Length of Grazing Cycle on Pasture Productivity

Total Dry Matter Accumulation

Dry matter accumulation is an important response in grazing trials because it measures the growth of herbage

since the last grazing. Total DM accumulation is the amount of live herbage summed over cycles that is considered available for the animals to consume over the season.

The model used for this response variable included the linear effects of RDM and GC and their interaction, because the quadratic effects were not significant. The complete second order model explained 87.8% of the variation, and the reduced model explained 87.4%; therefore, only 0.4% of the variation was explained by the quadratic effects. The regression analysis for the reduced model is presented in Table A-8.

Total DM accumulation increased linearly ($P<0.01$) from 1.7 to 9.5 Mg ha^{-1} as RDM and GC decreased (Fig. 12; Table A-2). The linear effect of RDM and GC explained 74 and 11% of the variation, respectively. There was RDM x GC interaction ($P=0.08$), which indicates that there was a slight difference in the slope of the effect of GC for each RDM. Note on Fig. 12 that the slope of the GC response when RDM was 2 Mg ha^{-1} was greater than that observed when RDM was 6 Mg ha^{-1}; similar responses can be observed over the entire grazing season (Figs. 4, 5, and 6). These data agree with Creek and Nestel (1965), who conducted an experiment evaluating the effect of two GC levels (32- and 40-d) on Pangola digitgrass. They measured DM production in terms of kg ha^{-1} d^{-1}, and

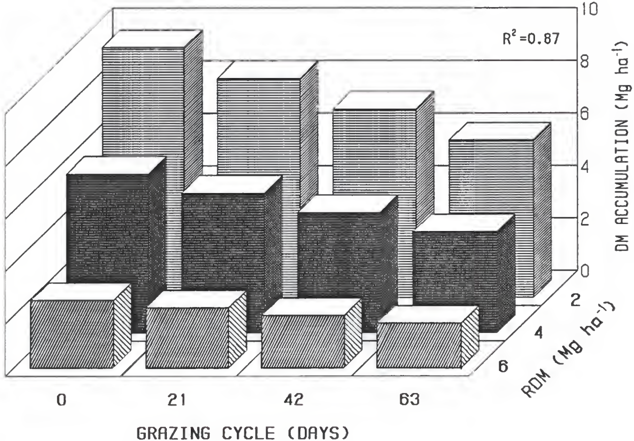

Fig. 12. Effect of grazing cycle and residual dry matter (RDM) upon total DM accumulation.

concluded that higher DM production was obtained from the shorter GC.

Unfortunately, few researchers have measured DM accumulation because it requires pasture measurements before and after each grazing period. The relationship between stocking rate and animal production has received a great deal of attention (Creek, 1970). He states that it is widely believed that higher levels of animal production area^{-1} are obtained at higher stocking rates. This statement suggests that higher DM accumulation is required to support more animals. He also mentions that this relationship should hold true up to the point that inadequate levels of feed are present, when production falls abruptly.

Total Dry Matter Consumption

Total DM consumption over the grazing season was similar to that of total DM accumulation, but there was only a linear effect of RDM ($P<0.01$). Nevertheless, there was a trend for total DM consumption to decrease linearly ($P=0.11$) as GC increased. Total DM consumption increased linearly from 2.5 to 10.2 Mg ha^{-1} (Fig. 13; Table A-2) as RDM decreased. This variable alone explained 83% of the variation in total DM consumption (Table A-9). In grazing trials one might expect that

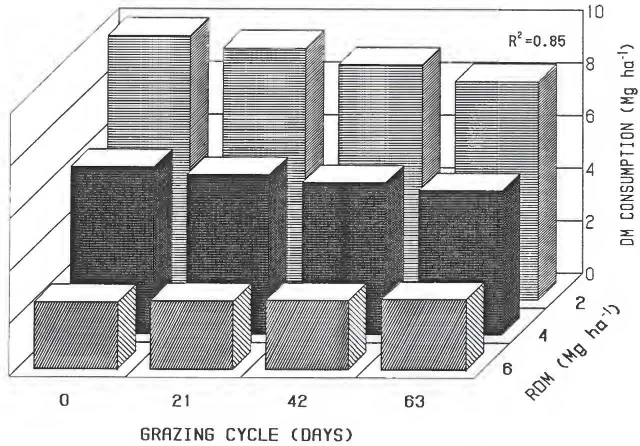

Fig. 13. Effect of grazing cycle and residual dry matter (RDM) upon total DM consumption.

rest period would have a greater effect on DM consumption, at least on a per animal basis. That is, with longer rest intervals the forage would be more mature and intake per animal should be lower. There are several studies that conclude that intake declines with advancing maturity of the herbage (Minson, 1971; and Minson, 1972). Nevertheless, due to the nature of this experiment, where RDM after grazing was the experimental variable, treatments with more mature forage were stocked with more animals in order to achieve the target RDM. As a consequence, the effect of maturity in longer rest interval treatments may have been masked.

Effect of Residual Dry Matter and Length of Grazing Cycle on Mean Seasonal Growth Rate

The linear effects ($P<0.01$) of RDM and GC explained 73 and 13% of the variation in growth rate, respectively (Table A-10). There was a RDM x GC interaction ($P=0.05$), which indicates that there was a difference in the slope of the growth rate response to GC at each level of RDM. Growth rate ranged from 1.4 g m^{-2} d^{-1} with the longest GC and highest RDM to 8.4 g m^{2} d^{-1} with continuous grazing and lowest RDM (Fig. 14; Table A-2). These data agree with those of Virguez (1965) who found growth rates of between 1.0 and 9.3 g m^{2} d^{-1} in Pangola digitgrass that was cut every 5 d between 10 and 45 d of maturity. In

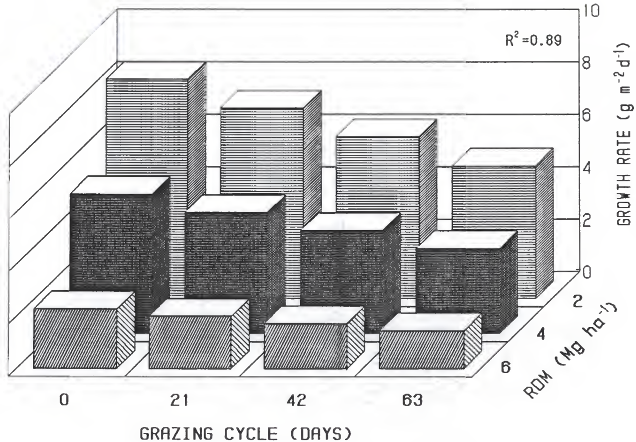

Fig. 14. Effect of grazing cycle and residual dry matter (RDM) upon mean growth rate.

another grazing experiment on 27 ha of well-established Pangola digitgrass, Creek and Nestel (1965) found higher growth rates with GC of 32 d than with a GC of 40 d. Cubillos (1975) conducted an intensive stargrass (Cynodon nlemfuensis Vanderyst) utilization study in Costa Rica, and he reported mean growth rates of 8.9 and 10.4 g m^2 d^{-1} for daily and weekly rotational systems, respectively.

It is important to be aware that growth rate studies are usually conducted as plot experiments where herbage is cut mechanically to ground level, and there are no fouling or treading effects of the grazing animal. It is risky to compare plot experiments with grazing studies. Higher growth rates with longer cutting frequencies are usually reported in plot experiments. Salette (1970) fertilized Pangola digitgrass plots with 50 kg N ha^{-1} and observed growth rates from 2 g m^2 d^{-1} with 30-d cutting frequency to 11 g m^2 d^{-1} with a 60-d cutting frequency. In grazing studies, it is difficult for the animal to remove all leaf or photosynthetic material. Higher growth rates at low RDM in the current study may be explained by assuming that the RDM left after grazing was sufficient to supply photosynthate for rapid initiation of regrowth. However, it is important to keep in mind that this experiment was only conducted during one season, and that the Pangola was well established and

carbohydrate reserves were probably high. It should also be noted that very little growth was obtained with RDM of 6 Mg ha^{-1} at any GC (Figs. 4, 5, and 6), perhaps for reasons including herbage maturity, leaf loss, leaf shading and an associated low photosynthetic rate, or treading damage.

Effect of Residual Dry Matter and Length of Grazing Cycle on Nutritive Value

Nutritive Value of Live Herbage Mass

Mean CP (Table 5) of pregraze whole-plant samples of Pangola digitgrass and glycine were 81 and 148 g kg^{-1} DM, respectively. Crude protein for Pangola digitgrass decreased quadratically ($P<0.01$; Table A-11) as GC increased and linearly ($P<0.01$) as RDM increased, the highest value being 90 and the lowest 71 g kg^{-1} DM. There was an interaction ($P<0.01$); therefore, the GC effect did not have similar slopes for each RDM. Crude protein for glycine ranged from 141 to 155 g kg^{-1} DM. It was not affected by RDM, but it increased linearly ($P=0.01$) as GC increased; nevertheless, there is doubt whether the difference is biologically important (Table A-12).

Mean IVDOM (Table 5) of pregraze whole-plant samples of Pangola digitgrass and glycine were 488 and 530 g kg^{-1}

Table 5. Crude protein (CP) and in vitro digestible organic matter (IVDOM) of pre-graze whole plant samples of Pangola digitgrass and glycine.†

Experimental variable	Pangola CP	Glycine CP	Pangola IVDOM	Glycine IVDOM
RDM‡	--- g kg^{-1} DM	----	--- g kg^{-1} OM	----
2	85	151	521	531
4	80	148	483	531
6	80	145	460	530
F test	L**	NS	L**	NS
GC§				
Cont.¶	83	143	487	526
21	90	141	497	519
42	82	151	484	531
63	71	155	484	545
F test	Q**,I**	L**,I	NS	NS
Mean	81	148	488	530

†Least squares regression analysis on Tables A-11 to A-14; Linear (L) or Quadratic (Q) effects, and Interaction (I) with probability of P<0.01 (**) or P<0.10 (letter without symbol), and NS = P>0.10.
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
§GC= grazing cycle (rest period + 4 d of grazing).
¶Cont.= continuous grazing (0 d rest).

OM, respectively. In vitro digestible OM for Pangola digitgrass was not affected by GC, but it decreased linearly ($P<0.01$; Table A-13) as RDM increased. Highest and lowest IVDOM were 521 and 460 g kg^{-1} OM. Glycine IVDOM was not affected by RDM or GC (Table A-14). The highest and lowest values were 545 and 519 g kg^{-1} OM, respectively.

Crude protein and IVDOM of whole-plant samples in grazing studies may be of little value because grazing animals do not eat whole plants. Moreover, comparison of these results with those available in the literature is difficult because most of that information comes from ungrazed plots, where the cutting height was kept constant; therefore, only the regrowth was sampled. For this reason the reported CP and IVDOM values in the literature are usually higher than those reported in this study. It is difficult to interpret the results of the current study because not only the new growth was sampled, but also included were the lower and more mature layers that had accumulated during prior cycles. It is likely that little difference was found between treatments because the large amount of mature forage included in the analysis masked the nutritive value differences of the regrowth. As expected, CP and IVDOM for Pangola digitgrass decreased with maturity, but surprisingly glycine CP and IVDOM increased with

increasing maturity. This may be explained because nutritive value of legumes does not decline with age as rapidly as tropical grasses, and that at longer GC there was a higher proportion of new growth relative to residual from previous cycles.

Another important point to note is that the regrowth interval of samples taken for the continuous treatment was 28 d; therefore, the forage was more mature than that from the GC of 21 d. This explains why the 21-d GC of Pangola samples had a higher nutritive value than did the continuous. Slightly higher CP and IVDOM at lower levels of RDM also can be explained because the samples have a lower proportion of mature forage compared to the whole sample mass.

Nutritive Value of DM Consumption

Crude protein and IVDOM of Pangola digitgrass and glycine consumed can be estimated from the pregraze and postgraze herbage mass determinations. These data were calculated by dividing total CP consumed (over cycles) for Pangola digitgrass or glycine by total DM consumed of that specie. Similar calculations were done for IVDOM, except on an OM instead of a DM basis. The accuracy of this method depends upon the accuracy of the herbage mass and botanical composition determinations. In general, it

is least effective when the difference between pregraze and postgraze herbage mass is small. In this experiment, coefficients of determination of the models were low, but the technique does give an estimation of the nutritive value of the DM consumed. Table 6 shows the CP and IVDOM of consumed Pangola digitgrass and glycine herbage. Crude protein and IVDOM for consumed herbage was higher than that of the whole-plant data. Mean CP values for Pangola digitgrass and glycine were 92 and 168 g kg^{-1} DM, respectively; and mean IVDOM values were 558 and 572 g kg^{-1} OM, respectively. In Table A-15 through A-18 are the regression analyses of CP and IVDOM of Pangola digitgrass and glycine consumed.

Crude protein of Pangola digitgrass consumed (Table 6) was similar to that found by Ventura et al. (1975), who reported CP values of 120 and 80 g kg^{-1} DM for 4- and 10-week maturities of Pangola hay, respectively. Similarly, Minson (1972) reported a Pangola CP mean of 108 g kg^{-1} DM. The IVDOM reported by Ventura et al. (1975) was higher (673 and 538 g kg^{-1} OM for 4- and 10-wk regrowth, respectively) than observed in this study. In a grazing experiment, Blydenstein et al. (1969) reported forage digestibilities for Pangola digitgrass that ranged from 503 to 657 g kg^{-1} DM, depending on the growing season. The digestibility was obtained by comparing the nutrient concentration of consumed forage with an

Table 6. Crude protein (CP) and in vitro digestible organic matter (IVDOM) of Pangola digitgrass and glycine consumed.†

Experimental variable	Pangola CP	Glycine CP	Pangola IVDOM	Glycine IVDOM
RDM‡	--- g kg^{-1} DM ----		--- g kg^{-1} OM ----	
2	91	145	550	604
4	93	172	588	565
6	91	175	519	569
F test	NS	NS	Q	NS
GC§				
Cont.¶	88	179	530	609
21	110	167	592	540
42	101	164	598	574
63	71	161	530	545
F test	Q**	NS	Q**	Q*,I
Mean	92	168	558	572

†Least squares regression analysis on Tables A-15 to A-18; Quadratic (Q) effect and Interaction (I) with probability of P<0.01 (**) or P<0.10 (letter without symbol), and NS = P>0.10.
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
§GC= grazing cycle (rest period + 4 d of grazing).
¶Cont.= continuous grazing (0 d rest).

analysis of fecal matter. With respect to glycine consumed, CP and IVDOM were in the range of those reported by Holder (1967). This author reported CP from 129 to 202 g kg^{-1} DM and digestibilities from 557 to 617 g kg^{-1} DM depending on the stage of growth. Pereiro et al. (1982 and 1983) reported CP for glycine of 180 and 198 g kg^{-1} DM, respectively.

Another way to estimate the nutritive value of the DM consumed is with the "hand-plucked" technique. It consists of taking a sample as similar as possible to the portion of the plants that the cattle are grazing and conducting the laboratory analyses on these samples. In this research hand-plucked samples were not taken, but it seems that in order to estimate the nutritive value of the forage consumed in grazing experiments, the hand-plucked technique may be more appropriate because it is not based upon the measures of herbage mass and botanical composition, which sometimes add large errors to the calculation.

SUMMARY AND CONCLUSIONS

Effect of grazing management on tropical grass-legumes pastures has been of increasing interest in tropical regions. Therefore, an experiment was conducted in Veracruz, Mexico, to evaluate a Pangola digitgrass and Clarence glycine pasture under three combinations of RDM after grazing, 2, 4, and 6 Mg ha^{-1}, and four lengths of GC, continuous, 21, 42, and 63 d. The objectives were to determine the effect of grazing management on productivity, persistence, and botanical composition of the association, and to estimate the nutritive value of the herbage mass and herbage consumed. Response variables measured included herbage mass (live and dead), botanical composition (Pangola, glycine, and weed percentage), DM accumulation, DM consumption, growth rate, and nutritive value (CP and IVDOM). These responses were statistically analyzed by least squares regression.

During the 147-d grazing season, mean live pregraze DM herbage mass decreased linearly (7.3 to 2.1 Mg ha^{-1}) as RDM and length of GC decreased. Mean dead pregraze DM herbage mass decreased linearly (3.0 to 0.6 Mg ha^{-1})

as RDM decreased. Glycine percentage decreased quadratically at a decreasing rate as RDM decreased and linearly as GC decreased (15 to 0%), but at low RDM, glycine percentage was low, regardless of GC. Total DM accumulation increased linearly (1.7 to 9.5 Mg ha^{-1}) as RDM and GC decreased. Total DM consumption also increased (2.5 to 10.2 Mg ha^{-1}) as RDM decreased, but there was only a linear effect of RDM. Forty-seven percent of the variation in mean live pregraze herbage mass, and over 74% in total DM accumulation and consumption were explained by RDM. Growth rate increased linearly from 1.4 to 8.4 g m^{-2} d^{-1} as RDM and GC decreased. Mean CP of pregraze whole-plant samples of Pangola digitgrass and glycine was 81 and 148 g kg^{-1} DM, respectively; and mean IVDOM was 488 and 530 g kg^{-1} OM, respectively. Mean CP for Pangola and glycine consumed was 92 and 168 g kg^{-1} DM, respectively; and mean IVDOM was 558 and 572 g kg^{-1} OM, respectively.

Conclusions based on this research include the following: 1) RDM was the major factor affecting botanical composition, DM accumulation, and DM consumption; 2) highest herbage mass and glycine percentage were achieved at high RDM and long GC; 3) highest DM accumulation, DM consumption, and growth rate occurred at low RDM and short GC; and 4) weed percentage was not affected by RDM nor GC. The results of this

study suggest that it may not be possible to maximize herbage accumulation or consumption and legume persistence with a specific grazing management. The author believes, however, that the legume may persist over a wider range of grazing managements than this study indicated. One possible reason for poor legume persistence is the way that the experiment was initiated. Herbage was allowed to accumulate to levels of approximately 8 Mg ha^{-1} (Figs. 4, 5, and 6) during the establishment phase. Therefore, large number of animal were put on the pastures during the first grazing period in order to achieve the target RDM. This may have caused greater detrimental effects to glycine than Pangola digitgrass, due to apparently higher selectivity of glycine and its greater susceptibility to treading. Another possible reason is that the animals used in the study were not accustomed to grazing small pastures, and it appeared that their grazing behavior may have been affected. Specifically, it seems that less time was spent grazing and more time walking the pasture than was typical of these cattle when they grazed larger pastures. Therefore, it is the concern of the author that treading effects were magnified resulting in greater loss of glycine at high RDM and long GC than might otherwise have occurred.

Throughout the literature review and the analysis of the data from this research, several concerns arose regarding grazing management research. The first important topic is the great confusion regarding terminology in grazing studies that is present in the literature. If one researcher uses the term "yield" when discussing herbage mass, and another uses "yield" when talking about DM accumulation or consumption, the conclusions reached may be opposite. Therefore, much caution is required while reading the grazing management literature and perhaps much more while planning and conducting research and writing the results. It seems better to avoid the term "yield" in grazing studies, and instead to use herbage mass, DM consumption, or DM accumulation, as defined by Hodgson (1979). Secondly, the use of whole-plant samples to conduct laboratory analysis to estimate nutritive value of the pasture may have little importance because grazing animals do not eat whole plants. Therefore, sampling the part of the plant that they are consuming will lead to more conclusive data. Thirdly, in grazing studies there is substantial variation in herbage mass and botanical composition within the experimental pasture. Therefore a fast, accurate, and non-destructive method to estimate these responses is necessary in order to take many samples per pasture. The author's opinion is that visual observation

can be a simple, fast, and very accurate double-sampling method if done by previously trained personnel. Fourthly, a greater awareness of regrowth mechanisms and competition of the grass and legume for soil nutrients is essential for the proper planning of an experiment and subsequent management of the association. Finally, the author believes that more research is required to study animal behavior on small pastures ($<500\ m^2$) to determine if management recommendations based on studies of this nature, particularly with grazing periods of 2 to 4 d, are useful in developing large scale production systems.

APPENDIX

Table A-1. Regression analysis between actual and target residual dry matter.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	1	53.65928756	53.65928756
ERROR	22	1.65516206	0.07523464
CORRECTED TOTAL	23	55.31444963	
MODEL F =	713.23		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	ARDM† MEAN
0.970077	7.0700	0.27428933	3.87962500

SOURCE	DF	TYPE I SS	F VALUE	PR > F
TRDM‡	1	53.65928756	713.23	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
TRDM	1	53.65928756	713.23	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.21700000	1.46	0.1571	0.14813317
TRDM	0.91565625	26.71	0.0001	0.03428617

†ARDM= actual residual dry matter (Mg ha^{-1}).
‡TRDM= target residual dry matter (Mg ha^{-1}).

Table A-2. Predicted values from the least squares regression analysis for each experimental variable.

Experimental variables†		Response variables‡							
RDM	GC	LHM	DHM	PPC	GPC	WPC	TDMA	TDMC	GR
Mg ha^{-1}	d	Mg ha^{-1}		%			Mg ha^{-1}		
2	0	2.12	0.85	92.16	0.00	7.86	9.52	10.16	8.35
2	21	3.44	0.78	92.16	0.41	7.65	8.35	9.54	7.25
2	42	4.76	0.70	92.16	1.37	7.43	7.17	8.91	6.15
2	63	6.07	0.62	92.16	2.34	7.22	5.99	8.29	5.05
4	0	4.03	1.41	85.41	3.42	9.54	6.05	6.35	5.31
4	21	4.93	1.55	85.41	4.38	8.73	5.31	6.06	4.62
4	42	5.82	1.69	85.41	5.35	7.92	4.58	5.77	3.93
4	63	6.71	1.82	85.41	6.32	7.11	3.84	5.48	3.24
6	0	5.95	1.97	78.66	12.45	11.22	2.57	2.54	2.27
6	21	6.41	2.32	78.66	13.41	9.81	2.28	2.58	1.99
6	42	6.88	2.67	78.66	14.38	8.40	1.99	2.62	1.71
6	63	7.34	3.03	78.66	15.35	6.99	1.69	2.67	1.43

†Experimental variables were residual dry matter (RDM) and grazing cycle (GC); GC = 0 d rest is continuous grazing.

‡Response variables were live herbage mass (LHM), dead herbage mass (DHM), Pangola digitgrass percentage in live herbage mass (PPC), glycine percentage in live herbage mass (GPC), weed percentage in live herbage mass (WPC), total dry matter accumulation (TDMA), total dry matter consumption (TDMC), and mean growth rate (GR).

Table A-3. Least squares regression analysis of live herbage mass.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	54.10567789	18.03522596
ERROR	20	0.87780307	0.04389015
CORRECTED TOTAL	23	54.98348096	

MODEL F =	410.92		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	LHM† MEAN
0.984035	3.9761	0.20949977	5.26904167

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	25.69613183	585.46	0.0001
GC¶	1	25.18206136	573.75	0.0001
RDM*GC	1	3.22748470	73.54	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	18.18440752	414.32	0.0001
GC	1	12.38826462	282.26	0.0001
RDM*GC	1	3.22748470	73.54	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.20100504	1.05	0.3066	0.19158497
RDM	0.95846596	20.35	0.0001	0.04708805
GC	0.08321382	16.80	0.0001	0.00495306
RDM*GC	-0.01020236	-8.58	0.0001	0.00118974

†LHM= live pregraze DM herbage mass (Mg ha^{-1}).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-4. Least squares regression analysis of dead herbage mass.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	12.34980941	4.11660314
ERROR	20	3.13681921	0.15684096
CORRECTED TOTAL	23	15.48662863	

MODEL F =	26.25		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	DHM† MEAN
0.797450	25.1110	0.39603151	1.57712500

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	11.08096225	70.65	0.0001
GC¶	1	0.45484817	2.90	0.1041
RDM*GC	1	0.81399900	5.19	0.0338

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	1.54163959	9.83	0.0052
GC	1	0.34822431	2.22	0.1518
RDM*GC	1	0.81399900	5.19	0.0338

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.29524982	0.82	0.4245	0.36216597
RDM	0.27907346	3.14	0.0052	0.08901370
GC	−0.01395146	−1.49	0.1518	0.00936311
RDM*GC	0.00512366	2.28	0.0338	0.00224905

†DHM= dead pregraze DM herbage mass (Mg ha^{-1}).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-5. Least squares regression analysis of Pangola digitgrass percentage in live herbage mass.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	1	629.48650343	629.48650343
ERROR	22	252.11685907	11.45985723
CORRECTED TOTAL	23	881.60336250	

MODEL F = 54.93 PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	PPC† MEAN
0.714025	3.9448	3.38524109	85.81625000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	629.48650343	54.93	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	629.48650343	54.93	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	98.90395999	52.16	0.0001	1.89626210
RDM	-3.37344717	-7.41	0.0001	0.45516652

†PPC= Pangola digitgrass percentage in live pregraze DM herbage mass.
‡RDM= residual dry matter after grazing (Mg ha^{-1}).

Table A-6. Least squares regression analysis of glycine percentage in live herbage mass.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	564.55006151	188.18335384
ERROR	20	111.17163432	5.55858172
CORRECTED TOTAL	23	675.72169583	

MODEL F =	33.85	PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	GPC† MEAN
0.835477	39.6885	2.35766446	5.94041667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	505.42313027	90.93	0.0001
GC¶	1	29.14863562	5.24	0.0330
RDM*RDM	1	29.97829562	5.39	0.0309

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	4.17796813	0.75	0.3962
GC	1	27.91909639	5.02	0.0365
RDM*RDM	1	29.97829562	5.39	0.0309

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.52135994	0.15	0.8854	3.57251722
RDM	-1.80479079	-0.87	0.3962	2.08173912
GC	0.04605568	2.24	0.0365	0.02055013
RDM*RDM	0.63206099	2.32	0.0309	0.27216829

†GPC= glycine percentage in live pregraze DM herbage mass.
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-7. Least squares regression analysis of weed percentage in live herbage mass.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	30.88585947	10.29528649
ERROR	20	122.85373636	6.14268682
CORRECTED TOTAL	23	153.73959583	

MODEL F = 1.68 PR > F = 0.2041

R-SQUARE	C.V.	ROOT MSE	WPC† MEAN
0.200897	30.0706	2.47844444	8.24208333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	6.80755064	1.11	0.3050
GC¶	1	17.79726333	2.90	0.1042
RDM*GC	1	6.28104550	1.02	0.3240

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	13.98404385	2.28	0.1470
GC	1	0.60025396	0.10	0.7578
RDM*GC	1	6.28104550	1.02	0.3240

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	6.17826811	2.73	0.0130	2.26650707
RDM	0.84051120	1.51	0.1470	0.55706555
GC	0.01831714	0.31	0.7578	0.05859619
RDM*GC	-0.01423261	-1.01	0.3240	0.01407498

†WPC= weed percentage in live pregraze DM herbage mass.
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-8. Least squares regression analysis of total dry matter accumulation.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	136.00531122	45.33510374
ERROR	20	19.52532774	0.97626639
CORRECTED TOTAL	23	155.53063896	
MODEL F =	46.44		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TDMA† MEAN
0.874460	19.2194	0.98806193	5.14095833

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	115.15463924	117.95	0.0001
GC¶	1	17.41861822	17.84	0.0004
RDM*GC	1	3.43205376	3.52	0.0755

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	59.76551474	61.22	0.0001
GC	1	10.63080125	10.89	0.0036
RDM*GC	1	3.43205376	3.52	0.0755

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	12.99906191	14.39	0.0001	0.90357053
RDM	-1.73761056	-7.82	0.0001	0.22208094
GC	-0.07708559	-3.30	0.0036	0.02336008
RDM*GC	0.01052072	1.87	0.0755	0.00561116

† DMA= total dry matter accumulation over the grazing season (Mg ha^{-1}).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-9. Least squares regression analysis of total dry matter consumption.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	159.18554123	53.06184708
ERROR	20	27.30241073	1.36512054
CORRECTED TOTAL	23	186.48795196	

MODEL F =	38.87	PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	TDMC† MEAN
0.853597	19.0532	1.16838373	6.13220833

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	154.31629954	113.04	0.0001
GC¶	1	2.91108116	2.13	0.1597
RDM*GC	1	1.95816053	1.43	0.2450

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	71.92918200	52.69	0.0001
GC	1	3.72376880	2.73	0.1142
RDM*GC	1	1.95816053	1.43	0.2450

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	13.97431668	13.08	0.0001	1.06847261
RDM	-1.90624920	-7.26	0.0001	0.26261082
GC	-0.04562276	-1.65	0.1142	0.02762331
RDM*GC	0.00794681	1.20	0.2450	0.00663520

† DMC= total dry matter consumption over the grazing season (Mg ha^{-1}).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-10. Least squares regression analysis of mean growth rate.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	104.26976313	34.75658771
ERROR	20	12.96467620	0.64823381
CORRECTED TOTAL	23	117.23443933	

MODEL F =	53.62	PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	GR† MEAN
0.889412	18.1016	0.80512969	4.44783333

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	86.01503767	132.69	0.0001
GC¶	1	15.29873900	23.60	0.0001
RDM*GC	1	2.95598647	4.56	0.0453

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	45.74578936	70.57	0.0001
GC	1	9.24127958	14.26	0.0012
RDM*GC	1	2.95598647	4.56	0.0453

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	11.39259095	15.47	0.0001	0.73628123
RDM	-1.52020682	-8.40	0.0001	0.18096432
GC	-0.07187143	-3.78	0.0012	0.01903514
RDM*GC	0.00976382	2.14	0.0453	0.00457230

†GR= mean growth rate (g m^2 d^{-1}).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-11. Least squares regression analysis of crude protein in pregraze Pangola digitgrass whole-plant samples.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	4	1407.78744803	351.94686201
ERROR	19	495.89088531	26.09952028
CORRECTED TOTAL	23	1903.67833333	
MODEL F =	13.48		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	PWPCP† MEAN
0.739509	6.2806	5.10876896	81.34166667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	157.77412641	6.05	0.0237
GC¶	1	527.42546939	20.21	0.0002
GC*GC	1	450.61649778	17.27	0.0005
RDM*GC	1	271.97135445	10.42	0.0044

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	394.54224945	15.12	0.0010
GC	1	4.03510039	0.15	0.6986
GC*GC	1	476.37383430	18.25	0.0004
RDM*GC	1	271.97135445	10.42	0.0044

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	100.25832105	21.08	0.0001	4.75688960
RDM	-4.46711156	-3.89	0.0010	1.14893723
GC	0.07418080	0.39	0.6986	0.18866032
GC*GC	-0.01010977	-4.27	0.0004	0.00236638
RDM*GC	0.09371957	3.23	0.0044	0.02903253

†PWPCP= Pangola whole-plant crude protein (g kg^{-1} DM).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-12. Least squares regression analysis of crude protein in pregraze glycine whole-plant samples.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	965.33967300	321.77989100
ERROR	18	1426.24396337	79.23577574
CORRECTED TOTAL	21	2391.58363636	

MODEL F =	4.06	PR > F = 0.0228

R-SQUARE	C.V.	ROOT MSE	GWPCP[†] MEAN
0.403640	6.0156	8.90144796	147.97272727

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM[‡]	1	69.82278130	0.88	0.3603
GC[¶]	1	600.52375731	7.58	0.0131
RDM*GC	1	294.99313439	3.72	0.0696

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	110.74030078	1.40	0.2525
GC	1	593.21847693	7.49	0.0136
RDM*GC	1	294.99313439	3.72	0.0696

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	128.69718651	12.26	0.0001	10.49766203
RDM	2.84730573	1.18	0.2525	2.40847370
GC	0.66709686	2.74	0.0136	0.24380478
RDM*GC	-0.10872634	-1.93	0.0696	0.05634942

[†]GWPCP= glycine whole-plant crude protein (g kg^{-1} DM).
[‡]RDM= residual dry matter after grazing (Mg ha^{-1}).
[¶]GC= grazing cycle (rest period + 4 days of grazing).

Table A-13. Least squares regression analysis of in vitro digestible organic matter in pregraze Pangola digitgrass whole-plant samples.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	1	15185.69120808	15185.69120808
ERROR	22	9147.34712526	415.78850569
CORRECTED TOTAL	23	24333.03833334	

MODEL F =	36.52		PR > F = 0.0001

R-SQUARE	C.V.	ROOT MSE	PWPDIG† MEAN
0.624077	4.1794	20.39089271	487.89166667

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	15185.69120808	36.52	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	15185.69120808	36.52	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	552.17342292	48.34	0.0001	11.42207484
RDM	-16.56906434	-6.04	0.0001	2.74168112

†PWPDIG= Pangola whole-plant in vitro digestible organic matter (g kg^{-1} OM).

‡RDM= residual dry matter after grazing (Mg ha^{-1}).

Table A-14. Least squares regression analysis of in vitro digestible organic matter in pregraze glycine whole-plant samples.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	1546.94658253	515.64886084
ERROR	19	8257.33167835	434.59640412
CORRECTED TOTAL	22	9804.27826088	
MODEL F =	1.19		PR > F = 0.3414

R-SQUARE	C.V.	ROOT MSE	GWPDIG† MEAN
0.157783	3.9305	20.84697590	530.39130435

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	8.20063311	0.02	0.8922
GC¶	1	1396.97475345	3.21	0.0889
RDM*GC	1	141.77119597	0.33	0.5746

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	139.59504828	0.32	0.5775
GC	1	569.97450706	1.31	0.2663
RDM*GC	1	141.77119597	0.33	0.5746

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	507.02130492	22.16	0.0001	22.87775135
RDM	3.02848387	0.57	0.5775	5.34359239
GC	0.63769509	1.15	0.2663	0.55683743
RDM*GC	−0.07395269	−0.57	0.5746	0.12948010

†GWPDIG= glycine whole-plant in vitro digestible organic matter (g kg^{-1} OM).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-15. Least squares regression analysis of crude protein in Pangola digitgrass consumed.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	
MODEL	2	4676.65610084	2338.32805042	
ERROR	18	7303.28961345	405.73831186	
CORRECTED TOTAL	20	11979.94571429		
MODEL F =	5.76		PR > F = 0.0116	
R-SQUARE	C.V.	ROOT MSE	PCPRO† MEAN	
0.390374	21.9935	20.14294695	91.58571429	
SOURCE	DF	TYPE I SS	F VALUE	PR > F
GC‡	1	1142.88903008	2.82	0.1106
GC*GC	1	3533.76707077	8.71	0.0085
SOURCE	DF	TYPE III SS	F VALUE	PR > F
GC	1	2284.77346655	5.63	0.0290
GC*GC	1	3533.76707077	8.71	0.0085

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	88.31596639	10.06	0.0001	8.77816516
GC	1.58220488	2.37	0.0290	0.66675174
GC*GC	-0.02950151	-2.95	0.0085	0.00999651

†PCPRO= Pangola consumed crude protein (g kg^{-1} DM).
‡GC= grazing cycle (rest period + 4 days of grazing).

Table A-16. Least squares regression analysis of crude protein in glycine consumed.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	3970.61704920	1323.53901640
ERROR	16	17914.87245080	1119.67952818
CORRECTED TOTAL	19	21885.48950000	
MODEL F =	1.18		PR > F = 0.3478

R-SQUARE	C.V.	ROOT MSE	GCPRO† MEAN
0.181427	19.9360	33.46161276	167.84500000

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	1599.00071622	1.43	0.2495
GC¶	1	1170.34124742	1.05	0.3218
RDM*GC	1	1201.27508556	1.07	0.3157

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	3.74880985	0.00	0.9546
GC	1	1816.99925611	1.62	0.2209
RDM*GC	1	1201.27508556	1.07	0.3157

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	181.23004893	4.34	0.0005	41.75648038
RDM	-0.54605276	-0.06	0.9546	9.43701777
GC	-1.58342759	-1.27	0.2209	1.24299019
RDM*GC	0.27630086	1.04	0.3157	0.26675212

†GCPRO= glycine consumed crude protein (g kg^{-1} DM).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-17. Least squares regression analysis of in vitro digestible organic matter in Pangola digitgrass consumed.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	4	25533.54484776	6383.38621194
ERROR	14	24512.40252066	1750.88589433
CORRECTED TOTAL	18	50045.94736843	

MODEL F = 3.65 PR > F = 0.0309

R-SQUARE	C.V.	ROOT MSE	PCDIG† MEAN
0.510202	7.5035	41.84358845	557.65263158

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM‡	1	82.42274873	0.05	0.8314
GC¶	1	290.85371500	0.17	0.6897
RDM*RDM	1	6796.98213395	3.88	0.0689
GC*GC	1	18363.28625009	10.49	0.0059

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	5824.60814047	3.33	0.0896
GC	1	17269.29365913	9.86	0.0072
RDM*RDM	1	5643.49280364	3.22	0.0942
GC*GC	1	18363.28625009	10.49	0.0059

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	405.76333367	5.70	0.0001	71.20790613
RDM	81.51122164	1.82	0.0896	44.69026889
GC	4.49870926	3.14	0.0072	1.43245030
RDM*RDM	-11.04864400	-1.80	0.0942	6.15409101
GC*GC	-0.07286979	-3.24	0.0059	0.02250097

†PCDIG= pangola consumed in vitro digestible organic matter (g kg^{-1} OM).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

Table A-18. Least squares regression analysis of in vitro digestible organic matter in glycine consumed.

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE
MODEL	3	14690.91860974	4896.97286991
ERROR	13	26978.48256673	2075.26788975
CORRECTED TOTAL	16	41669.40117648	
MODEL F =	2.36		PR > F = 0.1189

R-SQUARE	C.V.	ROOT MSE	GCDIG[†] MEAN
0.352559	7.9678	45.55510827	571.74117647

SOURCE	DF	TYPE I SS	F VALUE	PR > F
RDM[‡]	1	1198.83249681	0.58	0.4608
GC[¶]	1	5979.35456843	2.88	0.1134
RDM*GC	1	7512.73154450	3.62	0.0795

SOURCE	DF	TYPE III SS	F VALUE	PR > F
RDM	1	6282.78673312	3.03	0.1055
GC	1	10779.64115936	5.19	0.0402
RDM*GC	1	7512.73154450	3.62	0.0795

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	702.22092214	11.23	0.0001	62.55076701
RDM	-24.13127889	-1.74	0.1055	13.86887593
GC	-4.08672007	-2.28	0.0402	1.79312193
RDM*GC	0.72429436	1.90	0.0795	0.38067403

†GCDIG= glycine consumed in vitro digestible organic matter (g kg^{-1} OM).
‡RDM= residual dry matter after grazing (Mg ha^{-1}).
¶GC= grazing cycle (rest period + 4 days of grazing).

LITERATURE CITED

Anonymous. 1976. Tropical legumes increase milk production. Queensl. Agric. J. 102:331-333.

Blunt, C.G. 1978. Production from steers grazing nitrogen fertilized irrigated pangola grass in the Ord Valley. Trop. Grassl. 12:90-96.

Blydenstein, J., S. Louis, J. Toledo, and A. Camargo. 1969. Productivity of tropical pastures. 1. Pangola grass. J. Br. Grassl. Soc. 24:71-75.

Bogdan, A.V. 1977. Tropical pasture and fodder plants. Longman Inc., New York.

Bryan, W.W., and T.R. Evans. 1973. Effect of soils, fertilizers and stocking rate on pastures and beef production in the Wallum of south-eastern Queensland. 1. Botanical composition and chemical effects on plants and soils. Aust. J. Exp. Agric. Anim. Husb. 13:516-529.

Calvin, M., and A.A. Benson. 1948. The path of carbon photosynthesis. Science 107:476-480.

Canudas, E.G. 1984. Establishment of two cultivars of rhizoma peanut as affected by weed control and planting rate. M.S. Thesis, University of Florida, Gainesville, Florida.

Canudas, E.G., K.H. Quesenberry, D.H. Teem, and G.M. Prine. 1984. Sethoxydim and dalapon application to rhizomes for common bermudagrass control in rhizoma peanut. Soil Crop Sci. Soc. Fla. Proc. 43:174-177.

Conway, A. 1965. Grazing management in relation to beef production. IX Int. Grassl. Congr. Proc., Sao Paulo, Brazil. p. 1601-1607.

Conway, A. 1970. Grazing management for beef production. J. Br. Grassl. Soc. 25:85-91.

Cowan, R.T., I.J.R. Byford, and T.H. Stobbs. 1975. Effect of stocking rate and energy supplementation on milk production from tropical grass-legume pasture. Aust. J. Exp. Agric. Anim. Husb. 15:740-746.

Cowan, R.T., P. O'Grady, R.J. Moss, and I.J.R. Byford. 1974. Milk and fat yields of Jersey and Friesian cows grazing tropical grass-legume pastures. Trop. Grassl. 8:117-120.

Creek, M.J. 1970. Intensification of pasture production with beef breeding herds maintained upon improved pasture (Digitaria decumbens) in Jamaica. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 800-803.

Creek, M.J., and B.L. Nestel. 1965. The effect of grazing cycle duration on liveweight output and chemical composition of pangola grass (Digitaria decumbens Stent.) in Jamaica. IX Int. Grassl. Congr. Proc., Sao Paulo, Brazil. p. 1613-1618.

Crowder, L.V., and H.R. Chheda. 1982. Tropical grassland husbandry. Longman Inc., New York.

Cubillos, G. 1975. Intensive pasture utilization for milk production in the humid tropics. IX Annual Conf. on Livestock and Poultry in Latin Amer., University of Florida, Gainesville, Florida. A:30-37.

Davison, T.M., and G.W. Brown. 1985. Influence of stocking rate on the recovery of legumes in tropical grass-legume pastures. Trop. Grassl. 19:4-9.

De Carvalho, J.H. 1976. Plant age and its effects upon forage quality. M.S. Thesis, University of Florida, Gainesville, Florida.

Duble, R.L., J.A. Lancaster, and E.C. Holt. 1971. Forage characteristics limiting animal performance on warm-season perennial grasses. Agron. J. 63:795-798.

Eng, P.K., P.C. Kerridge, and L. 't Mannetje. 1978. Effects of phosphorus and stocking rate on pasture and animal productivity from a guinea grass-legume pasture in Johore, Malaysia. Trop. Grassl. 12:188-197.

Erdelyi, S., V. Tarau, V. Popescu, and M. Albu. 1987. Response of some species and mixtures of grasses and legumes to nitrogen fertilization. 1. Dry matter yield. Herb. Abstr. 57:330.

Evans, T.R. 1970. Some factors affecting beef production from subtropical pastures in the coastal lowlands of southeast Queensland. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 803-807.

Evans, T.R., and W.W. Bryan. 1973. Effects of soils, fertilizers and stocking rate on pastures and beef production on the Wallum of south-eastern Queensland. 2. Liveweight change and beef production. Aust. J. Exp. Agric. Anim. Husb. 13:530-536.

Febles, G., and C. Padilla. 1977. Efecto del acido sulfurico sobre la germinacion y el establecimiento de Glycine wightii. Rev. Cubana Cienc. Agric. 11:103-110.

Flores, G., J. Jimenez, X. Madrigal, F. Moncayo, and F. Takaki. 1971. Mapa de tipos de vegetacion de la Republica Mexicana. Direccion de Agrologia, Sec. Rec. Hidra. Galas de Mexico S.A., Mexico.

Gallaher, R.N., C.O. Weldon, and J.G. Futural. 1975. An aluminum block digester for plant and soil analysis. Soil Sci. Soc. Am. Proc. 39:803-806.

Gardener, C.J. 1975. Mechanisms regulating germination in seeds of Stylosanthes. Aust. J. Agric. Res. 26:281-294.

Gartner, J.A., and A.E. Fisher. 1966. Improving pastures in The Atherton Tableland. Queensl. Agric. J. 92:356-361.

Garza, R., A. Portugal, and A. Aluja. 1978. Produccion de carne con pasto pangola (Digitaria decumbens) solo o asociado con leguminosas tropicales. Tec. Pec. Mex. 35:17-22.

Garza, R., A. Portugal, and H. Ballesteros. 1972. Establecimiento de tres leguminosas tropicales en un potrero de zacate pangola. Tec. Pec. Mex. 22:5-11.

Gates, C.T., K.P. Haydock, and I.P. Little. 1966a. Response to salinity in Glycine. 1. G. javanica. Aust. J. Exp. Agric. Anim. Husb. 6:261-265.

Gates, C.T., K.P. Haydock, and P.J. Claringhold. 1966b. Response to salinity in Glycine. 2. Differences in cultivars of Glycine javanica in dry weight, nitrogen, and water content. Aust. J. Exp. Agric. Anim. Husb. 6:374-379.

Gilbert, M.A., and K.A. Shaw. 1979. The effect of heat treatment on hardseededness of Stylosanthes scabra, S. hamata cv. Verano and S. viscosa CPI 34904. Trop. Grassl. 13:171-175.

Gomes, D.T. 1978. Establishment methods and comparative persistence of five tropical legumes in grass sods. Ph.D. Diss., University of Florida, Gainesville, Florida.

Gray, S.G. 1962. Hot water seed treatment for Leucaena glauca (L.) Benth. Aust. J. Exp. Agric. Anim. Husb. 2:178-180.

Grof, B., and W.A.T. Harding. 1970. Dry matter yields and animal production of guinea grass (Panicum maximum) on the humid tropical coast of north Queensland. Trop. Grassl. 4:85-95.

Hambleton, L.G. 1977. Semiautomated method of simultaneous determination of phosphorus, calcium, and crude protein in animal feeds. J. Ass. Off. Ana. Chem. 60:845-852.

Hamilton, R.I., L.J. Lambourne, R. Roe, and D.J. Minson. 1970. Quality of tropical grasses for milk production. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 860-864.

Harris, W. 1978. Defoliation as a determinant of the growth, persistence and composition of pasture. In J.R. Wilson (ed.) Plant relations in pastures. CSIRO, Brisbane, Australia. p. 67-85.

Hatch, M.D., and C.R. Slack. 1966. Photosynthesis by sugar-cane leaves. A new carboxylation reaction and the pathway of sugar formation. Bioch. J. 101:103-111.

Hodgson, J. 1979. Nomenclature and definitions in grazing studies. Grass and Forage Sci. 34:11-18.

Holder, J.M. 1967. Milk production from tropical pastures. Trop. Grassl. 1:135-141.

Humphreys, L.R. 1980a. A guide to better pastures for the tropics and sub-tropics. 4th ed. Wright Stephenson and Co., New South Wales, Australia.

Humphreys, L.R. 1980b. Deficiencies of adaptation of pasture legumes. Trop. Grassl. 14:153-158.

Humphreys, L.R., and R.J. Jones. 1975. The value of ecological studies in establishment and management of sown tropical pastures. Trop. Grassl. 9:125-131.

Johansen, C., and P.C. Kerridge. 1979. Nitrogen fixation and transfer in tropical legume-grass swards in south-eastern Queensland. Trop. Grassl. 13:165-170.

Jones, R.M. 1979. Effect of stocking rate and grazing frequency on a Siratro (Macroptilium atropurpureum)/ Setaria anceps cv. Nandi pasture. Aust. J. Exp. Agric. Anim. Husb. 19:318-324.

Kennedy, M.M. 1962. Notes on the symbiosis of selected strains of rhizobia and Glycine javanica. Queensl. J. Agric. Sci. 19:425-428.

Klingman, D.L., S.R. Miles, and G.O. Mott. 1943. The cage method for determining consumption and yield of pasture herbage. J. Am. Soc. Agron. 35:739-746.

Kretschmer, A.E., Jr. 1970. Production of annual and perennial tropical legumes in mixtures with pangolagrass and other grasses in Florida. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 149-153.

Kyneur, G.W. 1960. Glycine on the Atherton Tableland. Queensl. Agric. J. 86:507-513.

Lopez, M., and J.J. Paretas. 1982. Estudio comparativo del rendimiento de materia seca y nitrogeno de glycine (Neonotonia wightii) y pangola (Digitaria decumbens Stent) en suelo rojo. Rev. Cubana Cienc. Agric. 16:285-295.

Lopez, M., E. Sistachs, F. Funes, T. Ruiz, M. Pereiro, and M. Monzote. 1981. Agrotecnia y utilizacion de leguminosas. Rev. Cubana Cienc. Agric. 15:195-210.

Ludlow, M.M., and G.L. Wilson. 1970. Studies on the productivity of tropical pastures plants. II. Growth analysis, photosynthesis, and respiration of 20 species of grasses and legumes in a controlled environment. Aust. J. Agric. Res. 21:183-194.

Ludlow, M.M., and G.L. Wilson. 1972. Photosynthesis of tropical pasture plants. IV. Basis and consequences of differences between grasses and legumes. Aust. J. Biol. Sci. 25:1133-1145.

Mannetje, L.'t. 1978. The role of improved pastures for beef production in the tropics. Trop. Grassl. 12:1-9.

Matches, A.G. 1987. Technique considerations in grazing management research. Proc. Southern Past. Forage Crop Improv. Conf.,43rd, Clemson, South Carolina. p. 49-50.

Matches, A.G., and J.C. Burns. 1985. Systems of grazing management. <u>In</u> M.E. Health, R.F. Barnes, and D.S. Metcalfe (ed.) Forages. 4th ed. Iowa St. Univ. Press, Ames, Iowa. pp. 537-547.

McIvor, J.G. 1983. The effect of seedbed preparation and sowing time on the establishment of perennial <u>Stylosanthes</u> species. Trop. Grassl. 17:82-85.

McLeod, M.N., and D.J. Minson. 1969. The use of the <u>in vitro</u> technique in the determination of the digestibility of grass/legume mixtures. J. Br. Grassl. Soc. 24:296-298.

Milford, R., and K.P. Haydock. 1965. The nutritive value of protein in subtropical pasture species grown in south-east Queensland. Aust. J. Exp. Agric. Anim. Husb. 5:13-17.

Milford, R., and D.J. Minson. 1965a. The relation between the crude protein content and the digestible crude protein content of tropical pasture plants. J. Br. Grassl. Soc. 20:177-199.

Milford, R., and D.J. Minson. 1965b. Intake of tropical pasture species. IX Int. Grassl. Congr. Proc., Sao Paulo, Brazil. p. 815-822.

Minson, D.J. 1967. The voluntary intake and digestibility, in sheep, of chopped and pelleted <u>Digitaria decumbens</u> (pangola grass) following a late application of fertilizer nitrogen. Br. J. Nutr. 21:587-597.

Minson, D.J. 1971. The digestibility and voluntary intake of six varieties of <u>Panicum</u>. Aust. J. Exp. Agric. Anim. Husb. 11:18-25.

Minson, D.J. 1972. The digestibility and voluntary intake by sheep of six tropical grasses. Aust. J. Exp. Agric. Anim. Husb. 12:21-27.

Minson, D.J. 1980. Relationships of conventional and preferred fractions to determine energy value. In W.J. Pigden, C.C. Balch, and M. Graham (ed.) Standardization of Analytical Methodology for feeds. International Development Research Center, Ottawa, Canada. pp. 72-78.

Minson, D.J., and R. Milford. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature Pangola grass (Digitaria decumbens). Aust. J. Exp. Agric. Anim. Husb. 7:546:551.

Monzote, M., F. Funes, and M. Garcia. 1982. Asociaciones de las leguminosas tropicales con pangola (Digitaria decumbens Stent.). Establecimiento. Rev. Cubana Cienc. Agric. 16:103-111.

Monzote, M., and M. Garcia. 1983. Asociaciones de leguminosas tropicales con pangola (Digitaria decumbens Stent) II. Evaluacion bajo pastoreo simulado y rehabilitacion. Rev. Cubana Cienc. Agric. 17:91-99.

Monzote, M., and T. Hernandez. 1977. Methods of oversowing perennial soybean (Glycine wightii) into pangola grass (Digitaria decumbens) and native pasture. XIII Int. Grassl. Congr. Proc., Leipzig, German Democratic Republic. p. 765-768.

Moore, J.E. 1980. Forage crops. In C.S. Hoveland (ed.) Crop quality, storage, and utilization, Am. Soc. Agron. and Crop Sci. Soc. Am., Madison, Wisconsin. pp.61-91.

Moore, J. E. 1981. Principles of forage quality evaluation. In King Visiting Scholar Lectures, Ark. Agric. Exp. Sta. Special Rept. 93, pp. 66-87.

Moore, J.E., and G.O. Mott. 1973. Structural inhibitors of quality in tropical grasses. In A.G. Matches (ed.) Antiquality components of forages. CSSA Spec. Pub. 4, Crop Sci. Soc. Am., Madison, Wisconsin. pp. 53-98.

Moore, J.E., and G.O. Mott. 1974. Recovery of residual organic matter from in vivo digestion of forages. J. Dairy Sci. 57:1258-1259.

Mott, G.O. 1959. Symposium on Forage Evaluation: IV. Animal variation and Measurement of Forage Quality. Agron. J. 51:223-226.

Mott, G.O. 1960. Grazing pressure and the measurement of pasture production. VIII Int. Grassl. Congr. Proc., Berkshire, England. p. 606-611.

Mott, G.O. 1977. Grazing management of tropical legume-grass association. XI Annual Conf. on Livestock and Poultry in Latin Amer., University of Florida, Gainesville, Florida. A:35-39.

Mott, G.O. 1981. Potential productivity of temperate and tropical grassland systems. XIV Int. Grassl. Congr. Proc., Lexington, Kentucky. p. 35-42.

Mott, J.J., S.J. Cook, and R.J. Williams. 1982. Influence of short duration, high temperature seed treatment in the germination of some tropical and temperate legumes. Trop. Grassl. 16:50-55.

Mott, J.J., and G.M. McKeon. 1982. Improved establishment of Stylosanthes hamata cv. Verano using heat-treated seed. Trop. Grassl. 16:43-46.

Mott, G.O., and J.E. Moore. 1985. Evaluating forage production. In M.E. Health, R.F. Barnes, and D.S. Metcalfe (ed.) Forages. 4th ed. Iowa St. Univ. Press, Ames, Iowa. pp. 422-429.

Mueller, J.P., and J.T. Green. 1987. Intensive grazing management. Proc. Southern Past. Forage Crop Improv. Conf.,43rd, Clemson, South Carolina. p. 51-53.

Neme, N.A. 1966. Seeds of perennial soybean. Results of scarification and duration of germinating capacity. Herb. Abstr. 36:117.

Neme, N.A. 1968. Scarifier "IAC" for seeds of perennial soybean (Glycine javanica). Herb. Abstr. 38:128.

Nestel, B.L., and M.J. Creek. 1962. Pangola grass. Herb. Abstr. 32:265-271.

Norman, M.J.T. 1970. Relationships between liveweight gain of grazing beef steers and availability of Townsville lucerne. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 829-832.

Osbourn, D.F. 1969. The introduction of pangola grass into the Caribbean islands. J. Br. Grassl. Soc. 24:76-80.

Partridge, I.J. 1975. The improvement of mission grass (Pennisetum polystachyon) in Fiji by topdressing superphosphate and oversowing a legume (Macroptilium atropurpureum). Trop. Grassl. 9:45-51.

Paterson, T., and R. Horrell. 1981. Leguminosas forrajeras en Santa Cruz, Bolivia. Prod. Anim. Trop. 5:46-57.

Paterson, R. T., C. Samur, and O. Bress. 1981. Efecto de pastoreo complementario de leguminosa reservada sobre la produccion de leche durante la estacion seca. Prod. Anim. Trop. 6:135-140.

Pereiro, M., A. Elias, and E. Munoz. 1983. Efecto de la suplementacion con concentrado en dietas de ensilaje y Neonotonia wightii en la produccion de leche. Rev. Cubana Cienc. Agric. 17:117-125.

Pereiro, M., J. Ugarte, A. Elias, and G. Zuaznabar. 1982. El efecto de dietas basadas en forraje, heno o ensilaje en el comportamiento de vacas lecheras en pastoreo restringido de Neonotonia wightii. Rev. Cubana Cienc. Agric. 16:243-248.

Philpotts, H. 1975. The effect of lime and Rhizobium strain on the nodulation of Glycine wightii and Macroptilium atropurpureum on acid soils. Trop. Grassl. 9:37-43.

Philpotts, H. 1981. Poor nodulation of lupins and tropical legumes in northern New South Wales. Aust. J. Exp. Agric. Anim. Husb. 21:588-594.

Rika, I.K., I.M. Nitis, and L.R. Humphreys. 1981. Effects of stocking rate on cattle growth, pasture production and coconut yield in Bali. Trop. Grassl. 15:149-157.

Roberts, C.R. 1980. Effect of stocking rate on tropical pastures. Trop. Grassl. 14:225-231.

Salette, J.E. 1970. Nitrogen use and intensive management of grasses in the wet tropics. XI Int. Grassl. Congr. Proc., Queensland, Australia. p. 404-407.

Santillan, R.A. 1983. Response of a tropical legume-grass association to systems of grazing management and levels of phosphorus fertilization. Ph.D. Diss., University of Florida, Gainesville, Florida.

SARH, 1986. Reportes climatologicos. Comision del Papaloapan. Oficina de Hidrologia, Medellin, Veracruz, Mexico.

SAS, Institute Inc. 1985. SAS user's guide: statistics. 5th ed. Author, Cary, North Carolina.

Shaw, N.H. 1978. Superphosphate and stocking rate effects on a native pasture oversown with Stylosanthes humilis in central coastal Queensland. I. Pasture production. Aust. J. Exp. Agric. Anim. Husb. 18:788-799.

Shaw, N.H., and L. 't Mannetje. 1970. Studies on a spear grass pasture in central coastal Queensland--The effect of fertilizer, stocking rate, and oversowing with Stylosanthes humilis on beef production and botanical composition. Trop. Grassl. 4:43-56.

Sistachs, M., E. Sistachs, and J.J. Leon. 1977. Control quimico de malezas y densidad de poblacion en establecimiento de la Glycine wightii. Rev. Cubana Cienc. Agric. 11:207-213.

Skerman, P.J. 1977. Tropical forage legumes. FAO Plant Production and Protection Series No.2. Food and Agric. Organization of the United Nations, Rome, Italy. p. 298-313.

Stobbs, T.H. 1969a. The effect of grazing management upon pasture productivity in Uganda. I--Stocking rate. Trop. Agric., Trin., 46:187-194.

Stobbs, T.H. 1969b. The effect of grazing management upon pasture productivity in Uganda. III--Rotational and continuous grazing. Trop. Agric., Trin., 46:293-301.

Stobbs, T.H., and P.A.C. Thompson. 1975. Milk production from tropical pastures. World Anim. Review 13:27-31.

Tergas, L.E. 1975. Factors affecting persistence of legumes in tropical legume-grass associations. IX Annual Conf. on Livestock and Poultry in Latin Amer., University of Florida, Gainesville, Florida. A:24-29.

Test, P.S. 1987. Vegetation and livestock response to three grazing systems--continuous, rotationally deferred and short-duration rotation. Herb. Abstr. 57:342.

Thomas, H. 1980. Terminology and definitions in studies of grassland plants. Grass and Forage Sci. 35:13-23.

Thomson, D.P., J.G. McIvor, and C.J. Gardener. 1983. The effect of seedbed type on the establishment of legumes and grasses at four sites in north Queensland. Trop. Grassl. 17:3-11.

Toledo, J.M. 1985. Pasture development for cattle production in the major ecosystems of the tropical American lowlands. XV Int. Grassl. Congr. Proc., Kyoto, Japan. p. 74-81.

Tow, P.G. 1967. Controlled climate comparisons of a tropical grass and legume. Neth. J. Agric. Sci. 15:141-154.

Ventura, M., J.E. Moore, O.C. Ruelke, and D.E. Franke. 1975. Effect of maturity and protein supplementation on voluntary intake and nutrient digestibility of pangola digitgrass hays. J. Anim. Sci. 40:769-774.

Virguez, O.A. 1965. Crecimiento de pasto estrella y pasto pangola. IX Int. Grassl. Congr. Proc., Sao Paulo, Brazil. p. 443-448.

Wheeler, J.L. 1962. Experimentation in grazing management. Herb. Abstr. 32:1-7.

Wheeler, J.L., J.C. Burns, R.D. Mochrie, and H.D. Gross. 1973. The choice of fixed or variable stocking rate in grazing experiments. Exp. Agric. 9:289-302.

Whiteman, P.C. 1969. The effects of close grazing and cutting on the yield, persistence and nitrogen content of four tropical legumes with Rhodes grass at Samford, south-eastern Queensland. Aust. J. Exp. Agric. Anim. Husb. 9:287-294.

Whiteman, P.C. 1972. The effects of inoculation and nitrogen application on seedling growth and nodulation of <u>Glycine wightii</u> and <u>Phaseolus atropurpureus</u> in the field. Trop. Grassl. 6:11-16.

Whiteman, P.C. 1980. Tropical pasture science. Oxford Univ. Press., New York.

BIOGRAPHICAL SKETCH

Eduardo G. Canudas-Lara was born on February 11, 1957, in Veracruz, Ver., Mexico. His parents are Dr. Eduardo W. Canudas-Orezza and Mrs. Martha Lara de Canudas.

He graduated in June of 1980 with the degree of Ingeniero Agronomo Zootecnista from the Instituto Tecnologico y de Estudios Superiores de Monterrey, in Monterrey, Mexico. Two years of his undergraduate program were spent at Texas A&M University in College Station, Texas.

Following the completion of his undergraduate studies, he worked for 2 years in the forage research program at "La Posta" Animal Experimental Station in Veracruz, Mexico, of the National Institute of Forestry, Agronomy, and Animal Science. In December of 1984 he received the Master of Science degree from the University of Florida, and began to pursue the degree of Doctor of Philosophy. He went to Mexico to conduct his dissertation field work. During that time he was employed in the Animal Science Department of CRECIDATH, a regional experimental station located in Veracruz, Mexico, from the Colegio de Postgraduados, Chapingo.

He is married to Judy K. Canudas, and they have two children, Eduardo and Lorena.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

K. H. Quesenberry

Kenneth H. Quesenberry, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W D Pitman

William D. Pitman, Cochairman
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

L. E. Sollenberger

Lynn E. Sollenberger
Assistant Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Charles J. Wilcox

Charles J. Wilcox
Professor of Dairy Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John E. Moore

John E. Moore
Professor of Animal Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as a partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1988

Jack L. Fry

Dean, College of Agriculture

Dean, Graduate school